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THE THIRD
SYMPOSIUM NEURORADIOLOGICUM

STOCKHOLM

SEPTEMBER 17—20, 1952

VOL. 40 AUGUST—SEPTEMBER Fasc. 2—3

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VOL. 40 AUGUST—SEPTEMBER 1953 FASC. 2—3

SYMPOSIUM NEURORADIOLOGICUM

STOCKHOLM

September 17—20, 1952

In 1939, a few physicians interested in the radiology of the skull came together with a view to discussing common problems. The idea emanated from THIENPONT in Antwerp, CHAUSSÉ in Paris and ZIEDSES DES PLANTES in Rotterdam, the meeting being held in Antwerp with THIENPONT presiding. This was the First Symposium Neuroradiologicum. It was felt to have been of such great value that before the participants separated they had decided to meet again within a few years.

The Swedish delegate to this First Symposium was ERIK LYSHOLM, who suggested that the next meeting should take place in Holland. The Great War then intervened, however, and the conference was postponed and was not to be held until 1949, when it took place in Rotterdam. By that time, both THIENPONT and LYSHOLM had died. The meeting was held under the presidency of Dr. ZIEDSES DES PLANTES. His

enthusiasm and self-sacrificing efforts made it possible for the Second Symposium Neuroradiologicum to be held in a country still bearing the scars of war.

The participants from the various countries represented at this meeting came to the decision that the Third Symposium should be held in September, not less than two years and not more than five years after the Rotterdam conference. The President of the Second Symposium was asked to suggest where it should be held, and Dr. ZIEDSES DES PLANTES subsequently entrusted Sweden with the organization of the Third Symposium Neuroradiologicum.

It is a great honour for our country to have been selected for this task. Above all, I regard it as a tribute offered in memory of the man, whom I consider to be — if not the founder of neuroradiology, yet the man who by his genius laid the foundations of what neuroradiology is to-day, an auxiliary science and an indispensable supplement to neurosurgery and neurology, if these sciences are to work in accordance with modern principles. It is scarcely necessary to mention his name in this connection, since everyone must know that I have ERIK LYSHOLM in mind. Because of his achievements, the original intention had been that he should be honoured with the presidency of the Second Symposium. This plan was reversed by his untimely death. Thanks, however, to Dr. ZIEDSES DES PLANTES and his associates, the arrangements for the Second Symposium were realized and this in a very admirable manner, not to be forgotten by anyone of those present in Rotterdam.

As was natural, the First Symposium was attended by very few. About ten times as many were present at the Second Symposium and twenty-four papers were read. For the Third Symposium, thirty-two papers were submitted. This is an indication that the idea the organizers of the First Symposium Neuroradiologicum had in mind has been justified and that these symposia represent the answer to a real need.

These meetings should be symposia and not congresses, that is, that every speaker must have the time he desires at his disposal. The word 'symposium' may also be taken to imply that each lecture should be delivered with the aim of stimulating exchanges of views and therefore be regarded as an introduction to a discussion.

At the meeting a presidential chain was received as a gift from the Board of the Second Symposium. The President of the Second Symposium, Dr. ZIEDSES DES PLANTES, upon presenting the chain, spoke as follows:

"During the last Symposium the representatives of the countries participating in the meeting authorized me to choose the place and a President for the next Symposium.

I first consulted several prominent neuroradiologists and it was not a matter of difficulty to decide that the next Symposium should be held in Stockholm and that our President should be Professor LINDGREN.

Mr. President, Sir! The members of the Board of the Second Symposium have great pleasure in offering you this presidential chain.

At first I was in doubt as to whether a presidential chain would not create too official a character to our meetings, agreed as we all are that their tone should be of a more friendly and intimate nature than is generally met with at an international congress. But my hesitation vanished on further consideration; I do not believe there is any risk of losing the character of our gatherings.

You will find on the chain three links bearing the name of THIENPONT who was the first President, that of the President of the Second Symposium and your own.

As a sign of your Presidential dignity during this Symposium, I now have much pleasure in placing the chain around your neck."

I should like to express our deeply felt gratitude for this magnificent gift. I am confident that I make myself the interpreter of a wish common to all participants of the Symposium in regarding this chain as a symbol for the future, representing a connecting link between the neuroradiologists of the world.

Erik Lindgren

The following lectures were read at the Symposium and are published in this issue of Acta Radiologica unless otherwise stated.

ANGIOGRAPHY

A. Vertebral angiography

Decker, K., München	The displacement of the posterior cerebral artery in vertebral angiograms.
Hoare, R. D., London	Arterio-venous aneurysm of the posterior fossa.
Olsson, O., Lund	Vertebral angiography.
Richter, Hs. R., Basel	Collaterals between the external carotid artery and the vertebral artery in cases of thrombosis of the internal carotid artery.
Sjögren, S. E., Stockholm	Percutaneous vertebral angiography.

B. Carotid angiography and phlebography

Fischgold, H. et al., Paris	Direct opacifying injections into the venous system of the head.
Gvozdanović, V. & Riessner, D., Zagreb	Angiographic studies in the problem of brain revascularization.
Johanson, C., Stockholm	The cerebral phlebogram by carotid angiography in cases of central brain tumours.
Löfgren, O., Lund	Carotid angiography in the diagnosis of spontaneous intracerebral haemorrhage.
Löfstedt, S., Stockholm	Angiography in intracranial arterial aneurysms. Further investigations. (Not received.)
Reid, R., Manchester	"Intracranial aneurysms", experiences in their radiological investigation. (Not received.)
Richter, Hs. R., Basel	Phlebography in brainstem tumours.

Discussion of angiography:

Columella, F., Milano.

Morson, S., Sydney.

Ziedses des Plantes, B. G., Rotterdam.

ENCEPHALOGRAPHY

ANDERSSON, T., Stockholm ..... Pneumographic diagnosis of meningeomata of the falx.

CHILDE, A. E., PARKINSON, D. & HOOGSTRATEN, J., Winnipeg .. Ventriculographic examination of the aqueduct of Sylvius and fourth ventricle.

DI CHIRO, G., Stockholm ..... The normal aqueduct. (Acta radiol. 39 (1953), 117.)

FALK, B., Stockholm ..... Encephalography in cases of intracranial tumour.

SHELDON, PH., Oxford ..... A cine radiographic investigation of air encephalography. (Not received.)

SUTTON, D., London ..... Radiologic aspects of pontine gliomata.

WICKBOM, I., Göteborg, & SHELDON, PH., Oxford ..... Some aspects of the radiologic diagnosis of posterior fossa and supra-sellar tumours.

ZIEDSES DES PLANTES, B. G., Rotterdam ..... Ventriculography with small amounts of air.

Discussion of encephalography:

FALK, B., Stockholm.

RUGGIERO, G., Stockholm.

TOMOGRAPHY

BOURDON, R. et al., Paris ..... Cranial tomography in neuroradiology. Tomography of the base of the skull.

Discussion of tomography:

GROS, C., Montpellier.

ZIEDSES DES PLANTES, B. G., Rotterdam.

MYELOGRAPHY

BULL, J. W. D., London ..... Spinal meningiomas and neurofibromas.

MOXON, C. P., Manchester ..... Myelography of the cervical spine. (Not received.)

ODÉN, S., Stockholm ..... Diagnosis of spinal tumours by means of gas myelography.

VARIA

LEFEBVRE, J., GUY, E. & METZGER, L., Paris ..... Evolution des signes radiographiques des atrophies cérébrales unilatérales.

LINDGREN, M., Lund ..... Roentgen treatment of gliomata.

McRae, D. L., Montreal ..... Bony abnormalities in the region of the foramen magnum. Correlation of the anatomical and neurological findings.

Discussion:

Stauffer, H. M., Philadelphia.

Sanchez-Perez, J. M., Hollywood Demonstration of a seriograph. (Not received.)

Sjögren, S. E., Stockholm ..... Experiences in localisation of brain tumours by means of diiodo^{131} fluorescein.

Sjögren, S. E. & Fredzell, G., Stockholm ..... Apparatus for serial angiography.

Fischgold, H., Paris ..... Survey of the Symposium.

FROM THE ROENTGEN DEPARTMENT (DIRECTOR: K. DECKER) OF THE NEURO-PSYCHIATRIC CLINIC (DIRECTOR: K. KOLLE), UNIVERSITY OF MUNICH, GERMANY

THE DISPLACEMENT OF THE POSTERIOR CEREBRAL ARTERY IN VERTEBRAL ANGIOGRAMS

by

K. Decker

Since the publications of LINDGREN, RADNER, and SUGAR appeared, vertebral angiography has developed into a useful method of neuroradiologic examination.

One soon learned to recognize typical signs such as pathologic vascularization of cerebellar haemangioblastomas. In addition, a series of thalamic spongioblastomas became evident through the typical appearance of the tumor vessels. Also, some acoustic tumors may be recognized either through their vascular pattern, or by the tumor being distinctly outlined by the displaced cerebellar vessels (Fig. 1).

It is also possible in some cases to diagnose an expanding lesion from the presence of a non-vascular area, for instance, in the case of certain occipital gliomas and large cerebellar astrocytomas. But it is to this day doubtful if there are any hard and fast rules governing vascular displacement in tumors of the vertebral area. While in carotid angiograms many growths are localized solely from the displacement of large vessels, this appears to be impossible in vertebral angiography. Our investigation was intended to clarify the degree of certainty with which tumors could be diagnosed without hypervascularization.

In a cursory comparison of several films, say of an occipital glioma or an ependymoma of the 4th ventricle, there seem to be no discernible differences (Figs. 2a & b). ECKER has described several types of vascular diplacement in the tentorian notch and the foramen magnum. But we, like WICKBOM, were unable to confirm his assertions. Thus today only the pressure of the basilar artery against the clivus and the straightening of the posterior artery signify a possible expanding lesion in the posterior cerebral fossa.

Fig. 1. Acoustic neurinoma. Small vessels surrounding the tumor showing displacement of the superior cerebellar artery.

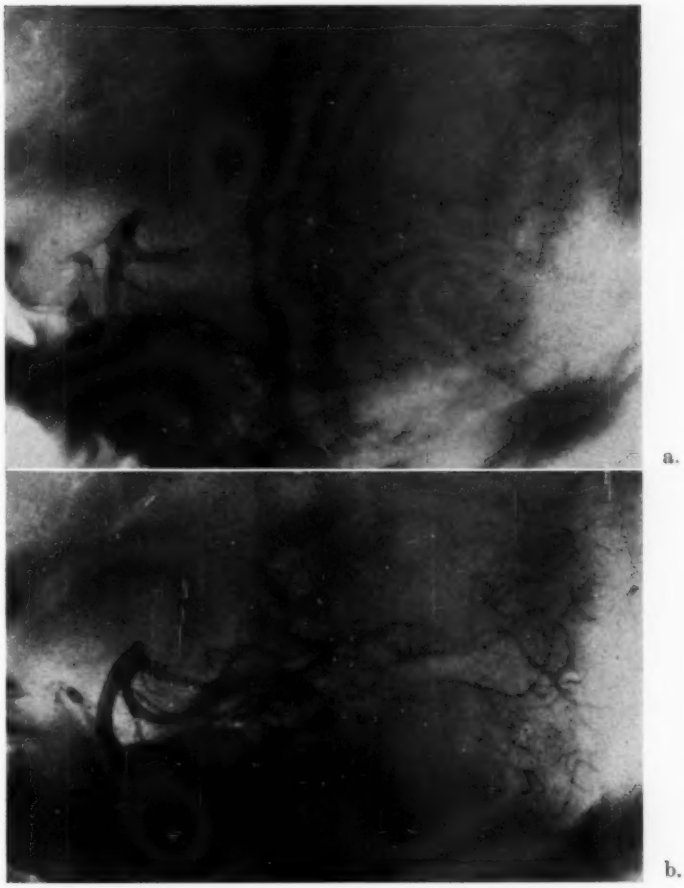
We attempted therefore to investigate in more detail the variations of the posterior cerebral artery in vertebral angiograms.

The course of the posterior cerebral artery in cases of extensive supratentorial growths and large infratentorial lesions may vary widely. This can best be seen from a comparison of the area below the artery in an occlusion of the aqueduct or a cerebellar astrocytoma. In the latter case one gains the impression of a broadening of the entire vascular area of the posterior cerebral fossa.

The determination of lesser changes of the course of the blood vessels is, however, very problematic.

We wanted to see if a relationship existed between the anatomically wellknown tentorial pressure cone and a displacement of the large vessels. Accordingly we attempted to mark the free edge of the tentorium to secure greater clarity. But as the entrance of the vein of Galen to the sinus rectus is highly variant, we obtained no results. Above all, the sinus rectus is usually situated higher in the skull when cerebellar tumors are present (as demonstrated by FISCHGOLD).

We then applied LYSHOLM's well-known method for obtaining average encephalograms to our own vertebral angiograms. We made a composite of all of films produced by the same technique. To compensate for variations in the skull formation, we chose certain fixed points in the



a.

b.

Fig. 2. a) Ependymoma of the IVth ventricle.
b) Occipital glioma. No discernible differences.

diagrams: (1) the clivus with the dorsum sellae and (2) the posterior border of the anterior cranial fossa and the direction of the coronal suture.

We were surprised at the similarity of the course of the posterior cerebral artery in normal cases. The positions of this artery in cases of cerebellar tumors also had much in common. The resultant diagram enabled us to recognize the various forms.

This comparative roentgen evaluation requires of course a standardized technique including centering.

Fig. 3. The area between the solid lines represents the course of the posterior cerebral artery in cases of intratentorial expanding lesions. In the area between the dotted lines lies the posterior cerebral artery in normal cases.

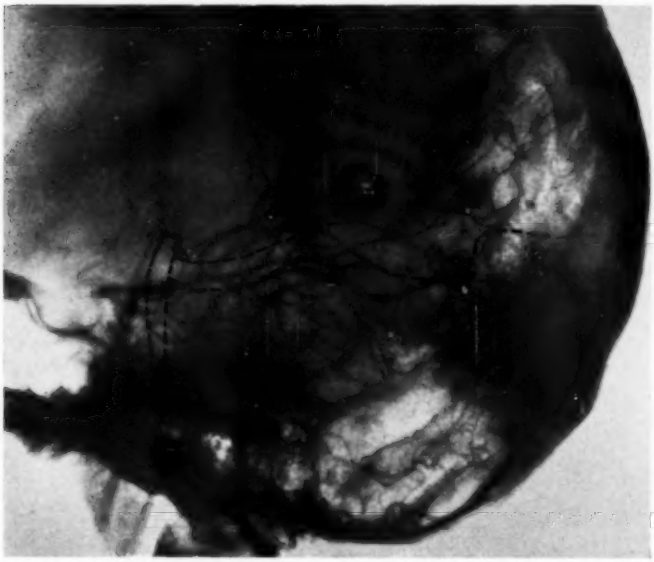


Fig. 4. Cerebellar astrocytoma. The posterior cerebral arteries are displaced upwards. The normal course of the artery is sketched in.

In evaluating the films we noticed that the upward displacement of the posterior cerebral artery begins in the middle third of the artery. Only in large tumors does this displacement also occur at the bifurcation of the basilar artery. In our opinion, this displacement is quite as important for the angiographic diagnosis of infratentorial expanding lesions as the pressing of the basilar artery against the clivus. In fully half of our cerebellar tumors, the vessels were distinctly displaced upwards. In no normal cases were we able to observe similar vascular conditions (Figs. 3 and 4).

The best evaluation of the usefulness of this method was obtained by reviewing our vertebral angiograms. We observed twenty-six cerebellar tumors in a series of a hundred and fifty vertebral arteriographies. Of these, only three cases showed a typical tumor vascularization permitting angiographic diagnosis. In an additional 20 % of the cases, the vascular displacement described was so distinct that it was possible to operate without ventriculography.

SUMMARY

The author discusses the question of vascular displacements associated with tumors in the posterior cranial fossa with particular reference to variations in the course of the posterior cerebral artery in vertebral angiography. In 20 % of a series of 150 cases, the displacement of the artery permitted of an angiographic diagnosis.

ZUSAMMENFASSUNG

Der Verf. diskutiert die Frage der Gefässverdrängung bei Tumoren der hinteren Schädelgrube unter besonderer Rücksichtnahme auf die Variationen im Verlauf der A. cerebri posterior bei der Vertebralisangiographie. In einer Serie von 150 Fällen erlaubte die Lageveränderung der Arterie in 20 % die Stellung der Diagnose mit Hilfe der Angiographie.

RÉSUMÉ

L'auteur étudie la question des déplacements de vaisseaux dans les cas de tumeur de la fosse postérieure, en particulier des variations de trajet de la cérébrale postérieure dans les angiographies vertébrales.

Sur une série de 150 cas, le déplacement de cette artère a permis un diagnostic angiographique dans 20 % des cas.

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FROM THE NEURORADIOLOGIC DEPARTMENT OF ST. GEORGE'S HOSPITAL, LONDON, ENGLAND

ARTERIOVENOUS ANEURYSM OF THE POSTERIOR FOSSA

by

R. D. Hoare

With the increasing use of carotid arteriography more and more cases of angioma or arteriovenous aneurysm of the cerebral hemispheres are being seen. Arteriovenous aneurysms of the posterior fossa are much more rare and only one reproduction of a vertebral arteriogram showing this type of lesion can be found in the literature (SUTTON and HOARE 1951). The case reported is included in this series. CUSHING and BAILEY (1928) described what they called a cerebellar Angioma Arteriale: they referred to a number of other cases which had been reported, the earliest being in 1911. DECKER (1952) writing on vertebral arteriography reports the demonstration of four angiomas or arterial anomalies but does not state if they are situated in the posterior fossa.

OLIVECRONA and RIIVES (1948) stated that arteriovenous aneurysms of the posterior fossa were rare and that the clinical picture was not characteristic. They reported four aneurysms, one of which was the first ever to be completely and successfully removed (1932); they predicted that until there had been much more experience most arteriovenous aneurysms of the posterior fossa would probably be discovered accidentally during exploration for presumed cerebellar tumour. The purpose of this paper is to report three such cases which support their prediction, but in which there were found signs which may in future facilitate diagnosis. These lesions were demonstrated by vertebral arteriography but in only one did this investigation precede surgery. At this time we had little experience in the application of vertebral arteriography to the diagnosis of posterior fossa expanding lesions.

Case I was seen last and showed most radiological signs. It was the observation of these signs that led to the review of the other two cases which showed signs which were not observed at the time these patients were under investigation. Just as enlargement of the carotid canal indi-

cates hypertrophy of the internal carotid artery in cases of large supratentorial arteriovenous aneurysm, so changes in the bones which form the canal through which the vertebral arteries pass indicate enlargement of the vertebral arteries. The groove or foramen in the posterior arch of the atlas and the foramen transversarium of the axis are usually seen on the lateral skull roentgenfilm and enlargement of them may be detected. In the full-axial view of the skull the foramina transversaria of the atlas are clearly seen, and enlargement or asymmetry may be noted. In addition, in this view, a very large jugular foramen may support the diagnosis. These changes may be confirmed by standard views of the cervical spine.

Increased vascularisation of the skull vault is already well known as a sign of supratentorial arteriovenous aneurysm, and if this is most marked in the posterior half of the skull it may suggest the presence of an infratentorial lesion.

In none of these cases was calcification seen in the lesion. All three showed hydrocephalus on pneumography, but in none were there definite signs of raised intracranial pressure in the survey views of the skull.

Case Reports

Case I. L. E. Male, age 24, was admitted for investigation after a subarachnoid haemorrhage from which he had made a slow recovery. He had noticed a tremor of the left hand several months before this illness.

On examination there was found deep pulsation in the sub-occipital areas on both sides thought to be due to the vertebral arteries. Loud systolic and faint diastolic murmurs were audible in these areas, in the occipital and temporal regions and over the right cheek. There were loud murmurs over the carotids and a thrill was palpable at the base

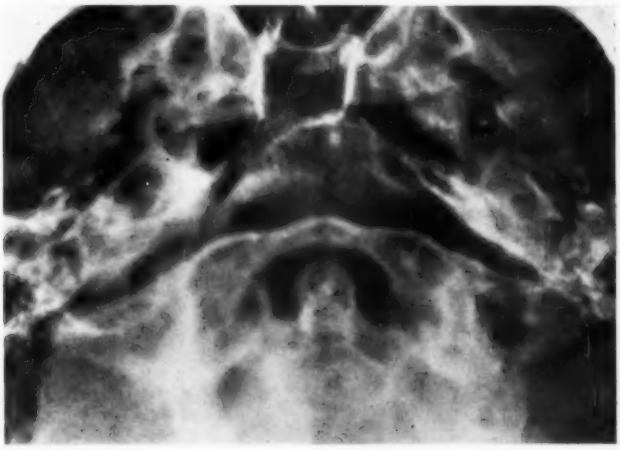

Fig. 1. Case I.

Full-axial view of skull. The foramina transversaria of the atlas and the right jugular foramen are enlarged.

Fig. 2. Case I. Oblique view of cervical spine showing enlarged foramina transversaria of the axis and deep grooves in posterior arch of the atlas.

of the neck on the right. The patient was not aware of these bruits. His face was highly-coloured and he had numerous pigmented raised naevi on his trunk. His pupils were unequal and he had nystagmus on looking upwards. Signs of a left cerebellar lesion were present.

Roentgen examinations: Chest: The heart was enlarged and a congenital cyst was present in the right lung.

Skull: Enlarged vascular channels were present on each side of the vault running from the temporal regions to the lambda. The one on the left was the larger and was straight, while that on the right was tortuous. The sella appeared normal. In the basal view the foramina transversaria of the atlas were shown to be enlarged, the left being larger than the right. The right jugular foramen was enlarged (Fig. 1).

Cervical spine: There were signs of enlargement of the whole of the bony pathway of the vertebral arteries on each side. (Figs. 2 and 3.) In particular there was enlargement of the left foramen transversarium of the axis and deep grooves were present in the posterior arch of the atlas.

Right carotid arteriography: This was performed first to see if the carotid contributed to the blood supply of the suspected aneurysm. This was negative and was followed by right vertebral arteriography. Left vertebral arteriography was performed several days later (Figs. 4, 5 and 6). Both showed equally well a large posterior fossa aneurysm fed by hypertrophied vertebral arteries which had proved to be easy to puncture. In the half-axial view the main bulk of the lesion was seen to occupy the left side of the posterior fossa but the arterialised veins obscured the feeding arteries.

Lumbar encephalography was attempted but as the air did not readily enter the ventricular system it was abandoned. Ventriculography: moderate hydrocephalus, the aqueduct was kinked and the fourth ventricle was displaced forwards.

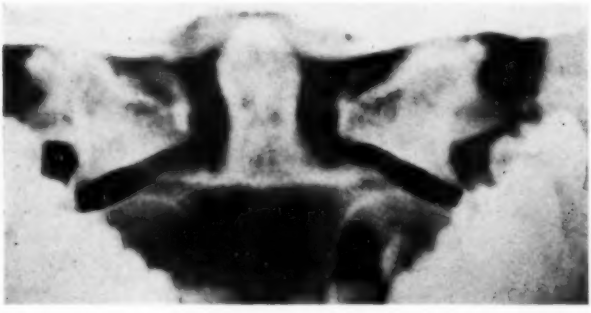

Fig. 3. Case I.

Frontal view of atlas showing thinning of the base of its left transverse process indicating hypertrophy of the vertebral artery.

Fig. 4. Case I. Right vertebral arteriogram (42.5 % diodone 10 ml). The large vertebral artery is seen end-on in the foramen transversarium of the axis and in the groove of the posterior arch of the atlas. The basilar artery is hypertrophied and the straight sinus is bulged backwards by the large mass of vessels.

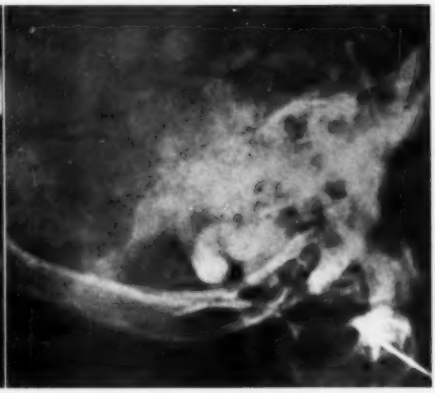

Fig. 5. Same case. Left vertebral arteriogram (50 % diodone). The hypertrophied vertebral artery and the aneurysm are well seen. Note the large artery just within the skull.

Exploratory craniotomy was performed in the hope of ligating entering arteries and to give the patient a decompression to relieve the hydrocephalus. Temporary occlusion of the large artery seen in the left vertebral arteriogram caused a fall of the blood pressure and it was not considered safe to proceed. At all events a very large number of entering arteries and arterialised veins were seen and it was clearly impossible to deal with all of them. The patient is alive and well without great disability two years after his subarachnoid haemorrhage.

Fig. 6. Same case. Left vertebral arteriogram. Frontal view showing mainly the draining veins which pass into the straight sinus.

Case II. B. B. Female, age 51. One year before admission, she fainted following exertion. She was reported to have been unconscious for one minute and from the time of this incident she experienced increasing stiffness and weakness of the right leg. Six months before admission she noticed her speech was slurred and one month before admission she had a severe attack of vomiting. On examination she was found to have a severe dysarthria, nystagmus maximal on looking to the right, right facial weakness of the upper motor neurone type, left facial spasm, and right pyramidal and left cerebellar signs in the limbs. Normal fundi. The skull films were at first interpreted as normal.

Fig. 7. Case II. Ventriculogram. Prone lateral view showing hydrocephalus with elevation of the floor of the third ventricle and obstruction at the mouth of the aqueduct.

Fig. 8. Same case. Left vertebral arteriogram. Lateral view after posterior fossa decompression. The enlarged vertebral artery can be seen faintly. The posterior fossa appears completely filled with abnormal blood vessels.

Fig. 9. Case III. Vertebral arteriogram. Frontal projection. Only the draining veins are seen clearly. They are seen passing round the mid-brain to enter the vein of Galen and straight sinus.

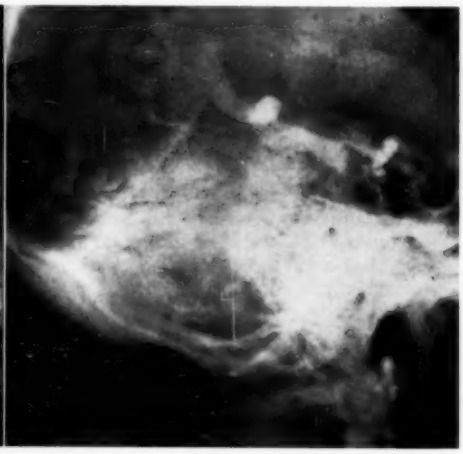

Fig. 10. Same case. Right vertebral arteriogram. Lateral view showing large vertebral and basilar arteries supplying the aneurysm in the region of the pons. Note the large tortuous draining veins entering the straight sinus.

Clinically there was thought to be an expanding lesion in the left side of the posterior fossa, and ventriculography was therefore performed (Fig. 7). This showed hydrocephalus together with elevation of the floor of the posterior part of the third ventricle. Neither the aqueduct nor the fourth ventricle could be filled. The posterior fossa was explored and the occipital bone and dura found to be very vascular. A tonsillar pressure cone was present. The right cerebellar hemisphere was found to be normal while the left was covered with tortuous arteries and veins, extending round to the pons and particularly involving the left VIIth and VIIIth cranial nerves. Treatment by decompression seemed to be the only possibility.

Left percutaneous vertebral arteriography was performed two weeks after craniotomy (Fig. 8). In order to obtain satisfactory films 47.5 % diodone had to be used. The aneurysm was shown in the lateral view. The half-axial view confirmed that the lesion was situated on the left side of the posterior fossa. This patient died soon after discharge but no necropsy was obtained.

On review of skull films it was seen that the left foramen transversarium of the atlas was enlarged and there was a deep groove in its posterior arch. There were tortuous vascular channels in the posterior part of the skull vault.

Case III. I. I. Male, age 22. Two years before admission he had begun to experience attacks of diplopia, which had become constant six months before admission. This case had been diagnosed and treated elsewhere as one of Myasthenia Gravis. He was admitted to the Neurosurgical Unit when he had developed symptoms and signs of raised intracranial pressure. He then showed early bilateral papilloedema; the left pupil was dilated, the right was constricted, and neither reacted to light or on convergence. There was restriction of ocular movements, strabismus and bilateral ptosis. Clinically there seemed to be a high pontine lesion.

Skull films showed no abnormality.

Ventriculography: Moderate hydrocephalus with elevation of posterior part of the floor of the third ventricle. The aqueduct was displaced backwards and upwards but the fourth ventricle could not be demonstrated.

The lesion was not thought to be operable and an anterior ventriculostomy was performed to relieve the hydrocephalus.

Post-operatively a right percutaneous vertebral arteriogram was performed in the hope of demonstrating the nature of the lesion, and this showed an arteriovenous aneurysm in the region of the pons. (Figs. 9 and 10.)

Review of the skull films showed signs in the atlas suggesting an enlarged vertebral artery. This patient is well two years after operation and is having operations to relieve his strabismus.

Conclusion

This is a small series of cases which may now be considered to have had incomplete investigation. They do show, however, the necessity for careful study of the atlas and axis in all posterior fossa lesions. On the ordinary films there may be detected signs suggesting the presence of an arteriovenous aneurysm in the distribution of the vertebral arteries.

Of the three cases described one presented as a subarachnoid haemorrhage and showed both clinical and radiologic signs which left no doubt of the diagnosis. The other two presented as space-occupying lesions and all showed to some degree signs of hypertrophy of the vertebral arteries. These signs are

1) Enlargement of the foramina transversaria of the upper cervical vertebrae,

2) Widening of the groove or foramen for the vertebral artery in the posterior arch of the atlas.

These radiologic signs should be evident in routine skull films and in addition there may be detected enlargement of the jugular foramen and also tortuous vessel markings in the lower and posterior part of the skull vault.

All three showed hydrocephalus with distortion of the aqueduct and fourth ventricle.

Acknowledgements

My thanks are due to Mr. Wylie McKissock, Mr. Valentine Logue and Dr. Denis Williams for permission to report their cases, and to Dr. James Bull for his help and encouragement. Also to Mr. Kenneth Paine who performed the arteriogram in Case III, and to the Photographic Departments of St. George's and Guy's Hospitals.

SUMMARY

Three cases of posterior fossa arteriovenous aneurysm demonstrated by vertebral arteriography are reported. Each shows in the ordinary roentgen films signs of hypertrophy of the vertebral arteries.

ZUSAMMENFASSUNG

3 Fälle, in denen ein arteriovenöses Aneurysma der Fossa posterior mit Hilfe der Vertebralisangiographie dargestellt worden ist, werden rapportiert. Jeder Fall zeigt auf den üblichen Röntgenaufnahmen Anzeichen einer Hypertrophie der Vertebralisarterien.

RÉSUMÉ

Présentation de trois cas d'angiome artério-veineux de la fosse postérieure, mis en évidence par l'angiographie vertébrale. Il y avait dans tous les cas, sur les radiographies simples, des signes d'hypertrophie des artères vertébrales.

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FROM THE ROENTGEN DIAGNOSTIC DEPARTMENT (DIRECTOR: PROFESSOR OLLE OLSSON)
OF THE UNIVERSITY CLINICS OF LUND, SWEDEN

VERTEBRAL ANGIOGRAPHY

by

Olle Olsson

Carotid angiography has been in use for many years and is now a routine diagnostic procedure. This is ascribable to the use of water-soluble contrast media of the diodrast type and to the use of the percutaneous technique for injection. The rapid development and wide use of carotid angiography indicated the need for a method of investigating the remaining sector of the cerebral vessels; in other words, it accentuated the requirement for vertebral angiography. In recent years this method has found more frequent use. We now have methods permitting the injection of the contrast medium without the troublesome exposure of the vertebral artery. The percutaneous puncture technique has been improved upon, in Sweden mainly by the work of LINDGREN. In addition a new method has been devised, namely via catheterization of the radial artery. This is described by RADNER of our department in Lund. An ordinary ureteric catheter, usually Nr. 6, is inserted via an incision in the radial artery, made at a level slightly proximal to the middle of the forearm. The catheter is then manipulated upwards into the vertebral artery. This technique is in all its details — and every detail is essential in the technique — described in Radner's monograph Vertebral Angiography by Catheterization, 1951.

A discussion of the procedure raises two obvious questions. How often is the method successful? and What complications have occurred?

As to the first question, RADNER reported failure in only 1 of 100 cases investigated after the final elaboration of the method. By failure, I mean that the catheter could not be passed up either side. In 2 cases, it was impossible to pass the catheter up the right side but no difficulty was encountered on the left side.

This technique has been used, since then, by us in a further 140 patients. In 3 of these, catheterization on the right side failed but the examination was completed by catheterizing the left side. In 1 case, the

examination was interrupted because of arterial spasm. I shall discuss this case later. If we now take the total number of cases of 240 examined by the method, we see that the technique failed in 1, the examination was incomplete in 1, and it failed on one side in 5, but was successful in these 5 cases when we catheterized the other side.

The series consists of patients of all ages, from early childhood to old age, and in which vertebral angiography was indicated. It should perhaps be mentioned that the catheterizations are performed not by only one but by several roentgenologists from the staff of the Roentgen Diagnostic Department.

As to the question of complications, the reaction that caused the most difficulty was arterial spasm. Nowadays, however, the patients are premedicated with 20 cg. papaverine sulfas intramuscularly just before the incision is made and the slight spasm, often previously encountered, is now rarely seen. In 2 cases, however, we were faced with serious situations. In one, a case of a middle-aged woman, severe arterial spasm occurred as the tip of the catheter was being passed through the subclavian artery. The catheter could not be withdrawn until the stellate ganglion was blocked. It should, however, be mentioned that the patient was very nervous and that the examination was carried out by a colleague who was trying the method for the first time. No attempts were made to resume the examination. In the second case the patient was a little girl. When the catheter was being withdrawn at the end of the examination a spasm occurred. A portion of arterial tissue was torn off by the catheter. No haemorrhage occurred nor was the blood supply to the area disturbed.

These were the only untoward reactions observed. In no instance were there signs of a disturbance of the blood supply, a side-effect that perhaps might be expected, due to ligation of the radial artery.

In none of our cases was the introduction of the catheter complicated by perforation of the vessel. We have heard of such an occurrence in a case examined elsewhere by an inexperienced operator.

Failure and untoward reactions in our cases were thus uncommon. Catheterization rarely failed and seldom were we faced with awkward situations arising from it.

As to the diagnostic value of the method, the results may perhaps be conveniently divided into two groups.

The first group (A) consists of those cases which gave results originally promised by the method almost from the outset. The second group (B) consists of those cases in which the results are as yet disappointing.

A. In the first group there are two conditions which naturally fall within the range of indications for vertebral angiography. The first of

these is the study of the vessels. Vertebral angiography is an indispensable adjunct to carotid angiography in the search for arterial aneurysms or in the study of the flow to arteriovenous aneurysms. This point requires no further discussion.

Secondly, vertebral angiography offers in the investigation of supratentorial tumours in the posterior part of the brain, roughly speaking, the same diagnostic possibilities as does carotid angiography in the investigation of the remainder of the brain. In this connexion the supratentorial central basal tumours such as pinealomas deserve special mention. Our experience in the investigation of these tumours is very limited, but nevertheless sufficient to justify the hope that vertebral angiography will prove a useful tool in the diagnosis of these tumours as well. Other tumours falling within the range of indications for vertebral angiography are the following types of infratentorial tumours:

1. Cerebellar haemangioblastomas, Lindau's disease

We have investigated 7 cases of haemangioma of the cerebellum and obtained a filling in 6. It is possible to diagnose all of the various types of haemangioma that LINDAU described in his classical monograph on the pathologic anatomy of these tumours.

2. Acoustic nerve tumours

We have examined 14 patients with acoustic neurinomas. No fewer than 9 of those cases showed vessels distinctly related to the tumour. In 5 cases there was no vessel related to the tumour but a displacement not only of the basilar artery but particularly of the superior cerebellar artery.

3. Miscellaneous infratentorial tumours

In the few cases dealt with, we have found vertebral angiography admittedly useful in the diagnosis but our experience is still too limited to permit of definite conclusions.

B. A few words on the group of cases in which vertebral angiography has, to a great extent, proved disappointing may not be out of place. When we started using this method I hoped that tumours such as medulloblastomas might be diagnosed and vertebral angiography would be just as informative as carotid angiography in the investigation of glioblastomas of the cerebrum. In no instance, however, we have observed vascular changes sufficiently characteristic to justify a diagnosis of medulloblastoma and thus spare the patient an operation. Nevertheless I think that with more accurate knowledge of the details of the infraten-

torial vascular pattern and with a better technique, we shall be able to advance a step or two in the right direction. The other disappointment was the establishment of tumour diagnosis by displaced vessels. The vertebral system is a sector with a much more primitive pattern than the carotid system. Unlike the latter, it does not bear such regular relationship to the midline. The vessels also vary widely from side to side and from one patient to another. But even on this point I feel that experience and a more detailed knowledge of the anatomy will in time enable us to judge displacement of various types better than we can today. It is also worth mentioning that any difference in the vascular pattern of the two sides may be explained not only by its variation on either side but by differences in the distribution of the flow of contrast medium at the bifurcation of the basilar artery.

Summing up, then, it may be said that we have found acceptable techniques for vertebral angiography. From a diagnostic point of view it offers indisputable and obvious advantages in the elucidation of certain conditions. But so far it has proved of little value in the diagnosis of some diseases. The percentage of tumours that can be defined with certainty by vertebral angiography without subsequent pneumography is still too small. It is, however, hoped that with time and further experience the diagnostic accuracy of vertebral angiography will increase.

(A more detailed report is published. See references.)

SUMMARY

The author reviews a material of 240 patients of all ages in which vertebral angiography was carried out by means of radial catheterization. Two cases in which complications arose are mentioned. The diagnostic value of the method is discussed and its present limitations in certain conditions pointed out.

ZUSAMMENFASSUNG

Der Verf. gibt einen kritischen Überblick über ein Material von 240 Patienten aller Altersgruppen, bei denen die Vertebralisangiographie mit Hilfe der Radialiskatheterisierung ausgeführt worden ist. Zwei Fälle, in denen Komplikationen eintraten, werden erwähnt. Der diagnostische Wert der Methode wird besprochen und deren gegenwärtige unter gewissen Umständen vorliegende Begrenzung wird hervorgehoben.

RÉSUMÉ

L'auteur passe en revue une série de 240 malades de tous âges chez qui l'angiographie vertébrale a été pratiquée par cathétérisation de la radiale. Il mentionne deux cas qui ont présenté des complications. Il examine la valeur diagnostique de cette méthode et souligne ses limites actuelles dans certaines affections.

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FROM THE NEURO-SURGICAL CLINIC (DIRECTOR: PROF. H. KRAYENBÜHL) OF THE UNIVERSITY OF ZÜRICH, SWITZERLAND

COLLATERALS BETWEEN THE EXTERNAL CAROTID ARTERY AND THE VERTEBRAL ARTERY IN CASES OF THROMBOSIS OF THE INTERNAL CAROTID ARTERY

by

Hs. R. Richter

The anatomy and topography of the vertebral artery have become more real since angiography has enabled us to examine this vessel in the living subject. Anatomists, such as TÖNDURY in his textbook of topographic anatomy, have already described small collaterals from the vertebral to the occipital artery in the muscles of the neck.

All our vertebral angiographies were performed by puncture at the level of the 4th or 5th cervical vertebra, as recommended by LINDGREN, SUGAR and DECKER, or by puncture between the atlas and the occiput, as carried out by MASLOWSKI. No open method or catheterization was used. The total number of our examinations was thirty.

Although our experience in vertebral angiography is therefore modest, we were rather surprised to find regular branches from the vertebral artery to the muscles of the neck in 25 of these 30 cases. These vessels showed segmental disposition, beginning with an initial branch between the occiput and the atlas, and which was frequently in duplicate. Further ramifications could be observed as low down as C4, although this area was but exceptionally included in the area examined. More or less pronounced arterial collaterals were found in the various cases, occasionally forming a rich arterial network in the muscles of the neck. Filling of the occipital artery also once occurred during vertebral angiography and draining of the collaterals into the deep cervical vein was observed (KRAYENBÜHL/RICHTER).

In addition to these anatomic findings, two cases of thrombosis of the internal carotid artery suggested to us the possibility of a compensatory irrigation from the occipital artery to the vertebral artery.

Fig. 1. Collaterals from the external carotid to the vertebral artery in a case of carotid thrombosis. Note the hypertrophic occipital artery connecting the external carotid to the vertebral artery. The basilar and posterior cerebral arteries are visualized.

Case 1: A patient, aged 54, suffering from a spastic motor and sensory hemiparesis of the left side following an apoplectic seizure five years previously. Repeated carotid arteriograms, performed percutaneously as well as by the open method, visualized only the external carotid artery. The lumen of the vessel was very irregular at the level of the (supposed) carotid bifurcation. A widened occipital artery irrigated a dense network of muscle branches in the neck and in spite of non-filling of the internal carotid artery, the basilar artery as well as the upper cerebellar and both posterior cerebral arteries were visualized, apparently via the hypertrophic collaterals from the occipital to the vertebral artery. As these vessels were of such great size, we believe that, from a practical point of view, a retrograde filling of the vertebral artery may be excluded (Fig. 1).

Case 2: A boy, aged 5 years, was examined two days after the appearance of a right-sided hemiplegia with aphasia. The angiogram of the left carotid artery showed complete thrombosis of the internal carotid artery and a very wide occipital artery.

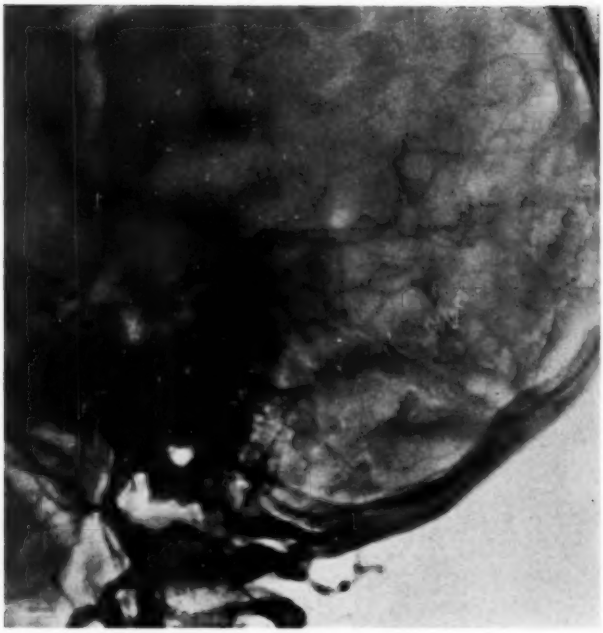

Fig. 2. Collaterals from the external carotid to the vertebral artery in the case of a boy two days after obstruction of the internal carotid artery. In spite of non-filling of the internal carotid artery, the posterior cerebral arteries are visualized through the widened muscle branches of the occipital artery.

From a rich arterial network, also present in this case, in the muscles of the neck, the contrast-medium reached the basilar artery. Both posterior cerebral arteries were visualized, no filling of the carotid siphon being evident (Fig. 2).

As mentioned, the vertebral artery very often gives muscle branches to the neck, and filling of the occipital artery may occur in vertebral angiography.

A further fact may be learnt from ontogenetic evolution, namely that the secondary muscles of the neck, *e. g.* the trapezoid muscle, originate from ventral myotomatas. The respective muscle artery, in this instance the occipital artery, follows the dorsal displacement of the muscle. Ontogenetics thus help us to appreciate the closed connections from the superficial, *i. e.* the occipital artery from the deep vessel, *i. e.* the vertebral artery. (In none of our cases a persistent carotid-basilar anastomosis could be observed as described recently by HARRISSON

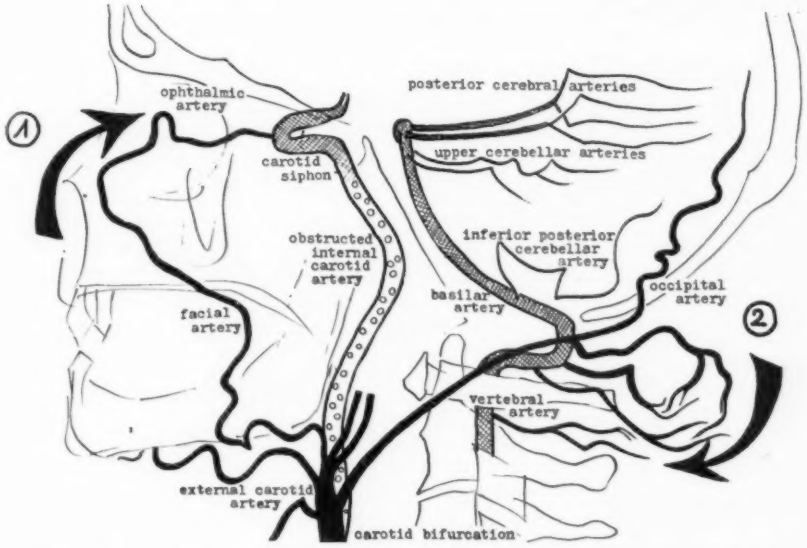

Fig. 3. Two possible collateral systems from the external carotid artery to the intracranial vessels: 1. via the facial—angular—ophthalmic arteries to the carotid siphon (MARX); 2. via the occipital artery and its muscle branches to the vertebral and basilar arteries.

and LUTTRELL. Cf. the embryologic studies on the cranial arteries by D. H. PADGET.)

In Case 2, carotid angiography demonstrated the compensatory irrigation from the external carotid to the vertebral artery two days after the onset of clinical signs of carotid thrombosis. One imagines that the collaterals were built up during the progress of the thrombosis before complete obstruction occurred. On the other hand, a congenital malformation must be taken into consideration.

In conclusion, we may say, that the three cases of collaterals between the external and internal carotid circulation in case of thrombosis of the internal carotid artery published by MARX and our own two cases show two routes of collateral irrigation of the brain arteries from the external carotid artery:

the first via the facial, the angular and the ophthalmic artery to the carotid siphon (MARX) and

the second via the occipital and the vertebral artery (Fig. 3).

SUMMARY

The author describes the demonstration of fine branches to the neck muscles from the vertebral artery in 25 out of 30 vertebral angiographies. In the 2 cases which are reported, a net-work of muscle branches was found in the neck and formed the collateral path via the occipital to the vertebral arteries.

ZUSAMMENFASSUNG

Der Verf. beschreibt feine Äste der A. vertebralis zu den Nackenmuskeln in 25 von 30 Vertebralisangiographien. In zwei der Fälle fand man im Nacken ein Netzwerk von Muskelästen, welches den Kollateralkreislauf zwischen den Aa. occipitales und Aa. vertebrales bildete.

RÉSUMÉ

L'auteur décrit de fines branches de l'artère vertébrale se rendant aux muscles du cou mises en évidence dans 25 angiographies vertébrales sur 30. Dans deux cas qui sont rapportés on a trouvé un réseau de branches musculaires qui assurait la voie collatérale entre les artères occipitales et vertébrales.

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FROM THE ROENTGEN DEPARTMENT (DIRECTOR: PROFESSOR ERIK LINDGREN),
SERAFIMERLASARETTET, STOCKHOLM, SWEDEN

PERCUTANEOUS VERTEBRAL ANGIOGRAPHY

A review of 250 cases

by

S. E. Sjögren

From a practical standpoint there are nowadays only two methods for contrast filling of the vertebral artery that need be discussed: the percutaneous and the catheter methods.

Our earlier technique in percutaneous puncture of the vertebral artery was described by LINDGREN in 1950. However, a little more than two years ago, certain modifications were made, and since then the technique has remained unchanged. These modifications consisted mainly of alterations in the direction of the puncture. The former technique consisted of directing the needle in a medial direction. We now execute the puncture in the following manner.

The examiner presses two fingers of the left hand in between the vessels and the trachea, which is pushed over to the normal side. The needle is then introduced through the skin near the midline. It is directed towards an intervertebral space 1—2 centimeters higher up, making the direction of the puncture obliquely — backwards, upwards, and somewhat outwards (Fig. 1). With this direction of puncture the needle tip, as a rule, will glide along

Fig. 1. Position of needle showing direction of puncture. A rubber tube has been inserted in the canal formed by the transverse foramina.

the groove on the inferior surface of the transverse process above the intervertebral space. It is led, so to speak, towards the vertebral artery, which it enters immediately before the latter ascends into the transverse foramen. Other advantages of the procedure are that the nerve plexus is practically never punctured and there is no risk of entering the subarachnoid space. ECKER (1951) seems to have arrived at the same opinion concerning the best direction of puncture. It is usually made with a relatively short-bevelled needle, since it is imperative that the bore should lie entirely within the lumen of the vessel. We have sometimes found it useful to employ a specially constructed needle which combines the advantages of a long-bevelled needle with an effective small bore (Fig. 2). The smaller opening has not affected the injection time. We have not found any special cervical level which is generally preferable and, in adults, use local anesthesia as a rule. The real problem in percutaneous puncture of the vertebral artery is to achieve and maintain a correct position o the needle tip in the vessel. Certain manipulations to facilitate this are part of our recent technique, but these minor details cannot be dealt with in this article.

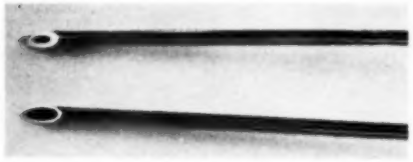


Fig. 2. Photograph of the eyes of two, otherwise identical needles; below: ordinary needle of Sebrecht type, above: the special needle for percutaneous puncture of the vertebral artery, with the tip partly filled in, making the opening smaller and less sharp-tipped.

Contrast media of the Diodrast (Iodopyracet) type are most suitable for all angiographic examinations, and at the present time we use the Swedish preparation Umbradil exclusively. According to our experience, it is less irritating than others. For precautionary reasons we never use a concentration higher than 35 per cent in angiography of the vertebral artery. In the great majority of cases, this affords quite sufficient contrast. The patients are tested, before the examination, for hypersensitivity to the medium, by means of intravenous injection. This is the only procedure we have found to give fairly satisfactory results.

In 1950 LINDGREN reported our first 60 vertebral angiography cases. Two of these suffered transitory but relatively alarming cerebral complications. In one of them, however, the examination had been performed with the catheter method. Since that time, in more than 200 cases, we have only once had a cerebral complication. This patient developed signs similar to those of thrombosis of the postero-inferior cerebellar artery. These gradually improved and after three weeks had almost disappeared. Otherwise, I have been unable to establish the occurrence of any complications. Accidental injection of the me-

dium into the wall of the vessel has not given rise to any untoward effects.

It has been our experience that Umbradil does not cause cerebral complications more frequently with percutaneous vertebral angiography than with carotid angiography. On the other hand, where the catheter method has been used, the number of complications appears to have been greater and their consequences more severe. Thus, RADNER has reported four such instances in a material of about 200 examinations. Two of these were fatal. In May 1951, in a paper presented before the Norwegian Neurologic Society, HAUGE reported his experience in 160 vertebral angiographies performed with catheters. He had observed that cerebral complications frequently occured with Umbradil 35 per cent, and reported two fatalities. He therefore recommended thorotrast in certain cases.

There is an obvious difference in the frequency of the complications. In the limited material available, this may, of course, be due to coincidence. The question is, however, whether the catheter method does not, in some way, facilitate an injurious effect by contrast media of the Diodrast type. In our opinion this seems likely. The catheter may easily form a partially occluding foreign body in the vessel, particularly when arterial spasms occur. When only a small quantity of blood can pass around the catheter, the dye, mixing with it, will of course be relatively more concentrated.

We consider thorotrast unsuitable for use in angiography. It is radioactive and is not excreted. Instead it is retained in the reticuloendothelial system. Furthermore, the changes arising from any extravascular injection are discouraging when percutaneous puncture is used.

Following the modification of the technique referred to above, the results have improved considerably. More than 150 cases have been performed with the new technique and only this series will be discussed here. It was possible to perform percutaneous vertebral angiography in all but two of the cases. (Both these patients were restless and confused. A second examination under general anesthesia was not performed.) In ten cases the filling of the intracranial branches of the vertebral artery was not satisfactory.

In the majority of cases the puncture was successful almost immediately so that the examination took no longer than a carotid angiography. However, no record was kept and I cannot give exact figures but should estimate that this applied to about 70 per cent of the cases. This is the same frequency as RADNER reports as the successful number of introductions of a catheter directly into the vertebral artery. Among the remaining cases, the percutaneous method encountered real difficulties

in about 10 to 15 per cent of the total. In some of these cases, this was due to the patient being confused, or unable to lie quietly for some other reason. The isolated cases in which it was impossible to persuade the patient to cease continual swallowing also belong to this group. Such movements may easily cause the needle to slip out of the vessel. In these cases the examination should, of course, not be further pursued under local anesthesia, but should be carried out under a general anesthetic. Another source of difficulties was of anatomic origin. It is very common for the two vertebral arteries to be of unequal caliber; not infrequently this difference is marked and one of the vessels is very narrow. Puncture should then be attempted bilaterally. Of course, in difficult cases, an experienced examiner obtains the best results, but percutaneous vertebral angiography has nevertheless been carried out successfully by many of the general staff of the Roentgen Department of Serafimerlasarettet.

A complete comparison between the percutaneous and catheter methods of vertebral angiography is naturally reserved for those with wide experience in both. However, in spite of our use of the catheter in only a relatively small number of cases in the beginning, we consider ourselves justified in drawing certain conclusions. Both methods are actually successful with approximately the same frequency, and the definitive results with the percutaneous method are only slightly inferior to those obtained by the RADNER catheter method. On the other hand, percutaneous puncture has certain advantages. It is less complex and may be performed with the same equipment as carotid angiography. Consequently, it may be carried out in conjunction with the latter if this seems advisable. If the clinical signs are unilateral, or if lateral localization has already been obtained radiologically, the examination should be performed on that side, because both vertebral arteries and hence the posterior inferior cerebellar arteries are only filled via unilateral injection in about one third of the cases. The choice of side is not limited in percutaneous puncture.

The routine performance of the examination from one side regardless of the nature of the case, as performed by RADNER, cannot be considered expedient. In addition, for one who is not especially trained, it is often difficult to pass the catheter up into the vessel and perforations have been reported. We have also had one such accident. From another angle, examination procedures requiring sterility and fluoroscopy at the same time, should, in my opinion, be avoided if possible. Whether or not ligation of the radial artery, necessary in the catheter method, can result in impaired circulation in the hand, remains an open question.

After presenting these objections, I must admit that when the cath-

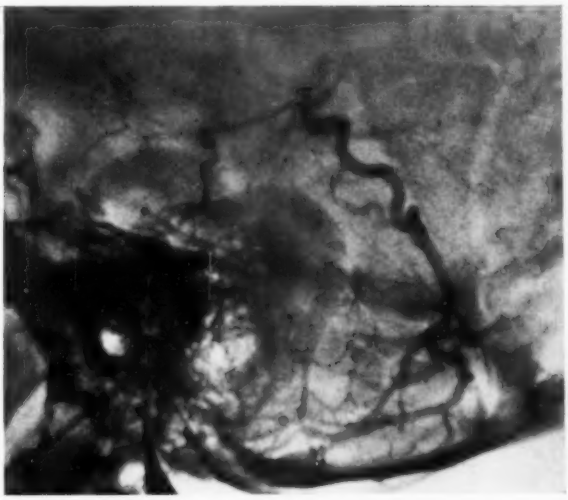


Fig. 3. Arteriovenous malformation in the posterior fossa consisting mainly of an arterialized vein in front of the straight sinus. The feeding artery emanates from the post. inf. cerebellar.

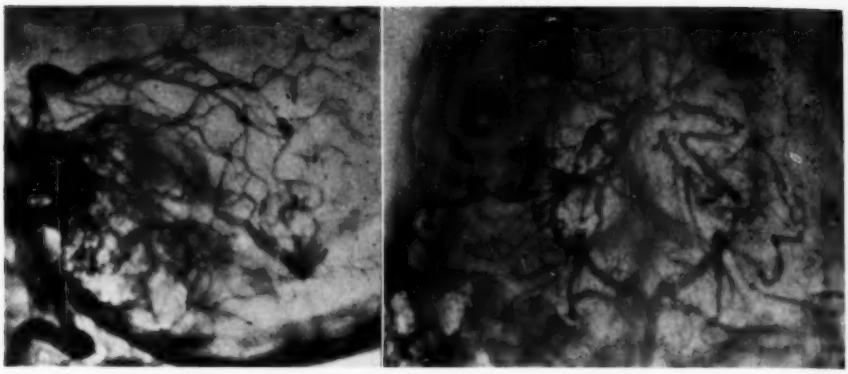
eter has been well placed in the vertebral artery, an ideal starting point for the continued examination has been attained. In our opinion, this is the real advantage of the catheter method.

Determination of the pathologic changes in the vessels themselves is the primary purpose of all angiographic examinations. The intracranial change of this kind attracting the greatest interest at the present time is the aneurysm; nowadays, all patients at Serafimerlasarettet, who have had subarachnoidal haemorrhages, are angiographically examined. Vertebral angiography is performed for two principal reasons: first, if an arteriovenous malformation has been found in carotid angiography, and second, if bilateral examination of the carotid artery is negative.

An arteriovenous malformation may be supplied from several sources through normal anastomoses alone, principally in the circle of Willis. The extent seems to depend upon anatomic conditions and the degree of the shunt, rather than upon the site of the lesion.

Accordingly, there is in our material a frontal malformation largely filled from the basilar artery via a dilated posterior communicating artery.

If the malformation lies near the region of the vertebral artery, there is the possibility that direct branches from the vertebral artery combine in the formation. Vertebral angiography is also performed in those cases in which bilateral examination of the carotid artery is nega-



a. b.

Fig. 4. a) lateral and b) a.-p. view of small arteriovenous malformation just above tentorium. Feeding artery: posterior cerebral. Filling of transverse sinus already in arterial phase.

tive. Of these we have discovered arteriovenous malformations in 7 cases. Three were supratentorial and supplied by the posterior cerebral artery; four were situated in the posterior fossa (Fig. 3). A local atrophy sometimes depends upon an arteriovenous malformation and is, therefore, in our opinion, an indication for angiographic examination. In the case shown in Fig. 4, only the posterior part of one of the lateral ventricles was dilated; carotid angiography was therefore carried out. The result was negative, but the posterior cerebral artery did not fill. As soon as this was observed, the examination was continued with a contrast injection into the vertebral artery.

We have not encountered any arterial aneurysms. This is contrary to our experience in carotid angiography and even to that of pathologists. It has led us to attempt to study the angles of the vessels a little more thoroughly than is possible in the usual projections by taking oblique views.

In cases of thrombosis of the internal carotid artery or certain of its branches, a collateral circulation through the vertebral artery appears and an exact idea of the vascularized area of the brain cannot be obtained without an examination of the vertebral artery. Arteriosclerotic and similar changes in the vessel walls have, of course, also occurred, in isolated cases associated with elongation of the basilar artery. If this artery for some reason extends unusually far up into the skull, it may cause an indentation in the floor of the third ventricle, rather characteristic in appearance (Fig. 5).

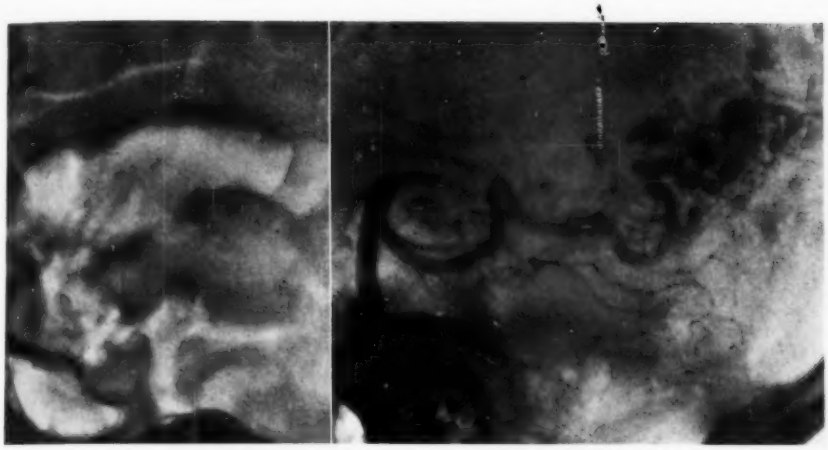


Fig. 5. Indentation in the floor of the 3rd ventricle caused by the elongated basilar artery in a case of arteriovenous malformation.

In the posterior cerebral fossa, the cerebellar angioreticulomas (the so-called Lindau tumours) are the growths most frequently showing hypervascularization. They are relatively common, and constitute, according to OLIVECRONA, more than seven per cent of all posterior fossa tumours. The hypervascularized part is sometimes very small, even microscopic, but in the majority of cases it seems possible to demonstrate it angiographically. This was RADNER's experience in five out of six cases and in our material, it was possible in five out of seven cases. One of our failures was a cystic recurrent tumour without a macroscopic solid part. As a rule, it is actually only the mural node in a cystic tumour which is demonstrated in this manner. The size of the cyst must be determined from the displacement of the vessels (Fig. 6). In one of our patients, multiple tumours were present. Pathologic vessels have also occurred in a few other tumours of various kinds.

Marked hydrocephalus produces a stretching of the intracranial branches from the carotid artery and a similar change also occurs in the region of the tentorial notch. It is incorrect, however, to assume that even a considerable hydrocephalus alone generally causes an accentuated stretching of these vessels.

Supratentorial expanding lesions in the anterior or middle part of the brain need not cause changes in the vessels belonging to the vertebral vessel system, although they may sometimes do so. This has been observed earlier, but its cause has seldom been discussed. The anterior part of the posterior cerebral artery is displaced basally in the tentorial

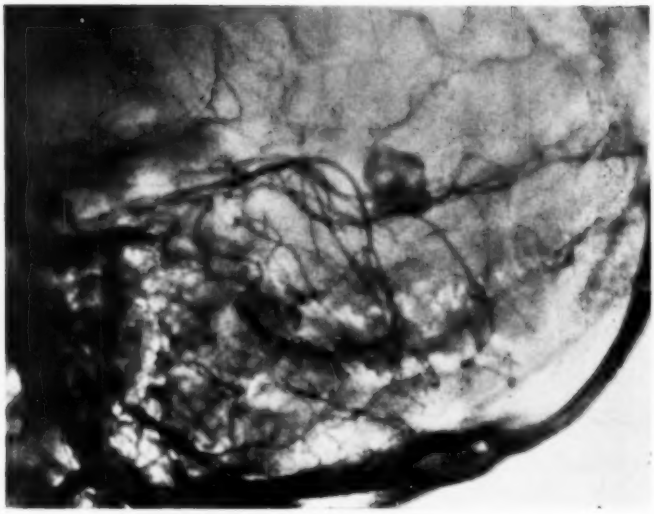


Fig. 6. Typical appearance of mural node in angioreticuloma. The size of the cystic part of the tumour may easily be determined from the displaced vessels. Note presence of multiple tumours.

notch. The vessel then runs at a sharp angle upwards around the posterior border of the notch to resume its position above the tentorium. In my opinion this change is due to the presence of a temporal pressure cone on one, or both sides. If unilateral, the corresponding posterior cerebral artery is usually also more or less pushed in a medial direction (Fig. 7).

The localisation of space-occupying lesions in the posterior fossa offers somewhat different problems than in the cases of supratentorial processes. The additional difficulties are mainly the consequence of the anatomic conditions present. Thus, in lateral views the vessels from both sides appear superimposed and, as in a. p. views, the posterior cerebral artery and particularly its temporal branches partially cover the superior posterior cerebellar artery and its branches. The differentiation between them is facilitated by the presence of more than one a.-p. film, obtained with a somewhat different tube angulation. Moreover, especially in lateral and axial views, large areas of the posterior fossa are obscured by the bony structure. Additional difficulties are introduced if branches from the external carotid artery are simultaneously filled with contrast medium via anastomoses with the vertebral artery.

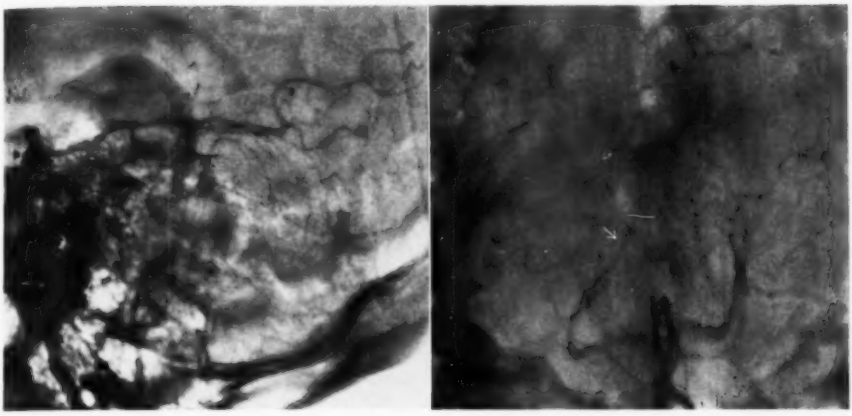
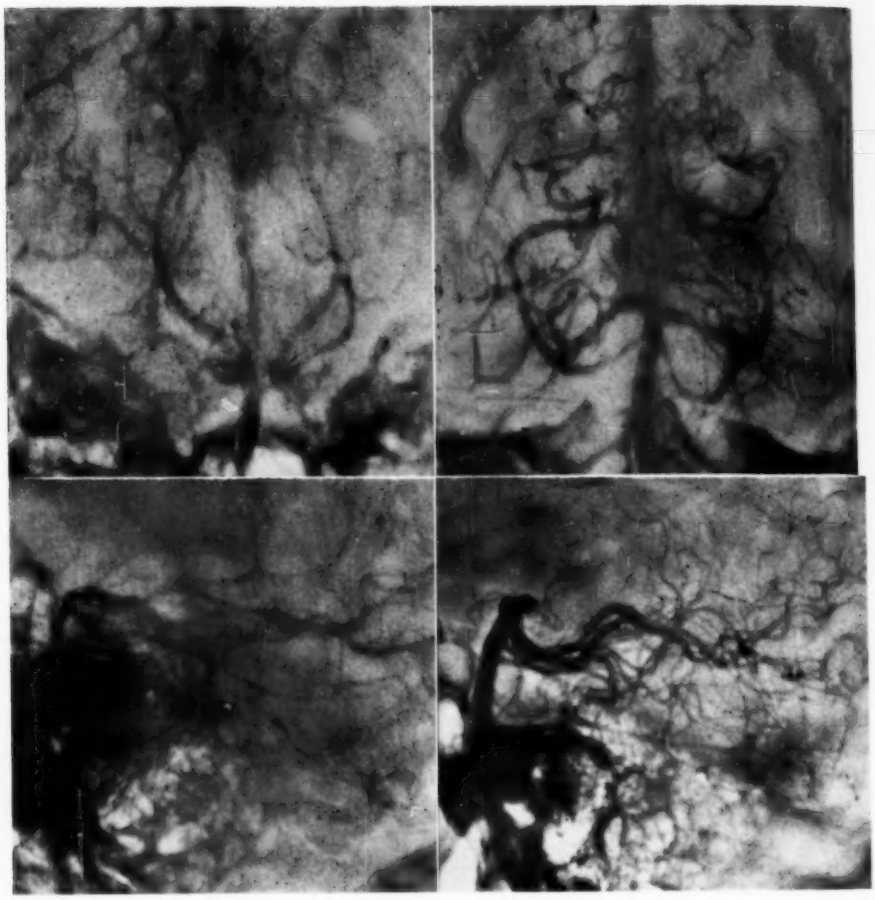


Fig. 7. Step-like depression of the vessels in the tentorial notch and medial displacement of left posterior cerebral artery in a case with large frontal meningeoma (temporal pressure cone).

Furthermore, a comparison of the vascularization of the two sides is possible only in cases in which the medium has passed over into the contra-lateral vertebral artery. In the majority of cases, this does not occur, and consequently the posterior inferior cerebellar artery is visualized only on one side. Finally, there are frequent variations in the vascular arrangement and in this connection I should like to call attention to one variation which appears to be less well known but nevertheless is of great significance, namely the greatly varying length of the basilar artery (Fig. 8). The course of the vessels stretched by a short basilar artery especially may be misinterpreted as due to a pathologic process.

The numerous anatomic variations of the posterior inferior cerebellar artery also seem to be very little known. We have found this vessel to be of great diagnostic value and I have therefore commenced a series of special post-mortem examinations. I should, however, like to stress certain points. The artery is unfortunately sometimes absent or too narrow to be clearly visible in roentgenograms. It generally arises from the vertebral artery 1—2 cm before the bifurcation and then turns around the medulla oblongata in a tortuous loop and enters the vallecula. It has close relations with the cerebellar tonsil, whose lower pole it crosses. After reaching the vallecula, the artery continues in an upward and backward direction for about 2 cm, close to the midline and often in a somewhat tortuous manner. As a rule it divides into two main branches. The lateral branch gives off a number of smaller branches

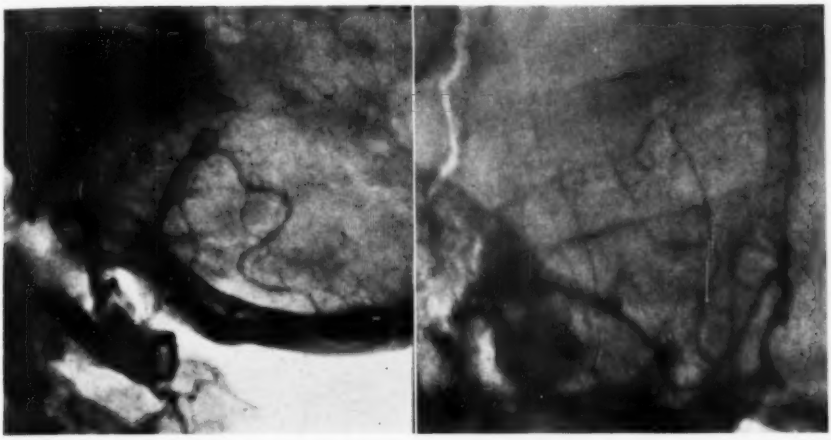


a. b.

Fig. 8. Anomalies. a) Unusual short basilar artery. b) Long basilar artery extending high up. Note the influence on the appearance of the branches.

supplying the lower surface of the cerebellum. The medial branch continues its course close to the midline (Fig. 9).

Expanding processes in the posterior fossa usually cause herniation of parts of its content, upwards through the tentorial notch or downwards through the foramen magnum, sometimes both. These herniations cause displacement of adjacent vessels and it is thus possible to demon-



a. b.

Fig. 9. Normal cases. The posterior inferior cerebellar artery and its medial and lateral branches in a) lateral, b) a.-p. view (see text).

strate them angiographically. On the other hand, such changes often contribute to the localisation of the pathologic process itself. In questionable cases, the level of the tentorial notch may be gauged if the posterior clinoid process and the posterior border of the notch, obtainable from the phlebogram, are combined in a slightly curved line. In foraminal herniation through the foramen magnum, the posterior inferior cerebellar artery follows the cerebellar tonsils downwards and is more or less deformed (Fig. 10).

With the exception of these changes due to herniations, the vascular displacements in the posterior fossa are similar to those above the tentorium. The change in the vessels that occur in the neighbourhood of a tumour is of great significance. The stretching of small vessels is, for example, a rather important sign in pontine angle tumours. The expanding process may be surrounded by stretched arch-shaped arteries or veins. If such an avascular area has a position as in Fig. 11, it may also be caused by a markedly dilated fourth ventricle. Displacement of the basilar artery has localising significance mainly in certain extracerebellar tumours, such as meningeomas and chordomas, but otherwise the displacements of the larger vessels are of no special interest apart from the already mentioned changes in herniations. The course of a part of the posterior inferior cerebellar artery and its medial branches close to the midline makes them suitable for the lateral localisation of processes (Fig. 12).

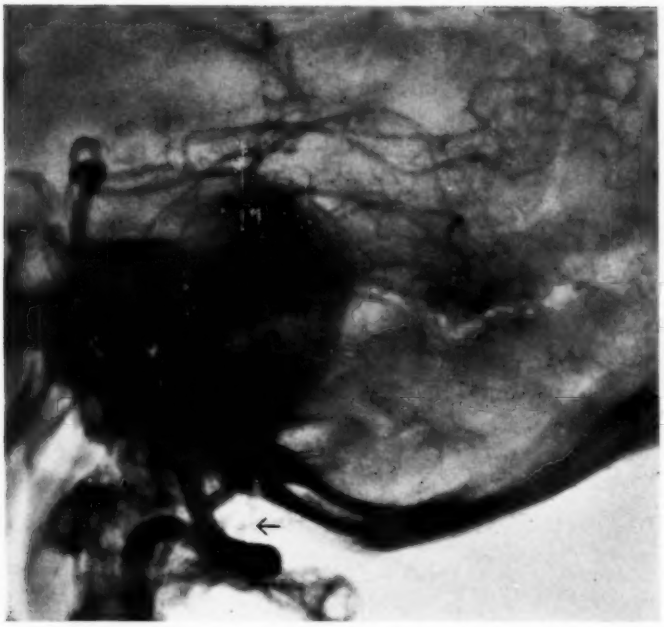


Fig. 10. Cerebellar angioreticuloma. Depressed tonsils with displacement of posterior inferior cerebellar artery (arrow). Herniation of superior posterior cerebellar artery upwards through tentorial notch. (No hypervascularized area is visible.)

Our material of expanding lesions in the posterior fossa comprises 38 cases. Of these, 11 are extracerebellar. In the majority of the cases, histologic examination was performed, but in some isolated instances of inextirpable tumours biopsy was not carried out, and three were not operated upon. The localisation in the latter, however, was perfectly clear through pneumographic examination. In addition, there were four cases with suspected vascular displacements and in which verification has not yet been obtained.

With the help of the signs, briefly described above, we have been able to demonstrate the presence of an expanding lesion in the posterior fossa in all the verified 38 cases except one. In four it was, however, possible to tell that there was an expanding process present, although its exact localisation was impossible. In the remainder, the lesion was localised, but in a few cases not as precisely as by pneumography. We have, for instance, in some cases only been able to localise the tumour

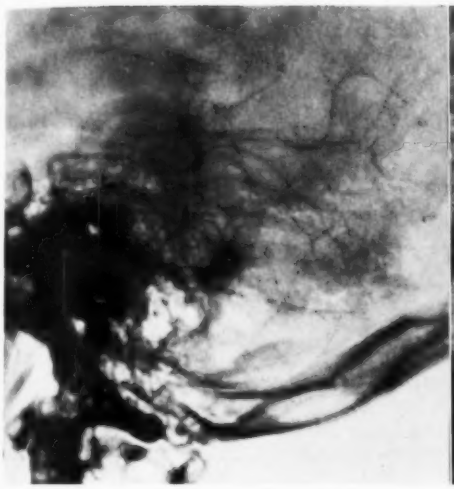


Fig. 11. Lateral view showing large, avascular area in the middle of the posterior fossa surrounded by stretched vessels in a case of medulloblastoma of the 4th ventricle. (See also text.)

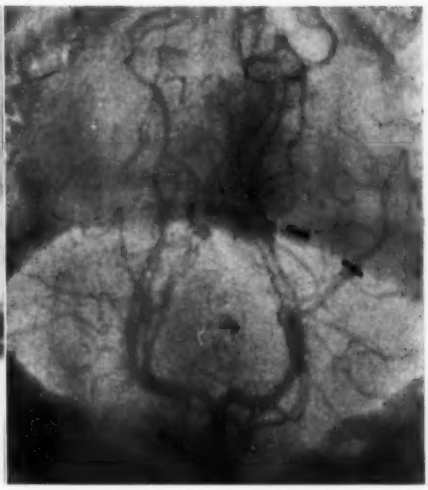


Fig. 12. Lateral shift of posterior inferior cerebellar arteries and their medial branches (arrow) in a case of cystic recurrence of cerebellar angioreticuloma.

to the midline, but not to determine whether it was situated in the pons or in the vermis. Angiographic localisation is now more exact than it was a few years ago, but still not as reliable as pneumographic localisation. This is, in our opinion, essentially due to incomplete knowledge of the numerous anatomic variations. It is therefore actually inexpedient to attempt to eliminate the possibility of a tumour in the posterior fossa by vertebral angiography alone.

Angiographic localisation is on the other hand especially applicable in cases where an operation has already been performed, inasmuch as the conditions necessary for localisation with encephalography can be more or less destroyed by the operation. Our material also includes a high percentage of suspected recurrences.

SUMMARY

The main features of the technique for percutaneous vertebral angiography employed in the Roentgen Department of Serafimerlasarettet, Stockholm, during the last two years are described. The results, in 150 cases, seem to be comparable to those obtained by the catheter method. The percutaneous method furthermore appears to have certain advantages, and must therefore be considered a highly justifiable first

choice. Using Umbradil 35 %, only once has a minor cerebral complication occurred and no permanent injuries have been recorded.

A short review is given from the total material of 250 cases. Special attention is directed to the possibility of localising even poorly vascularized expanding lesions in the posterior fossa and the importance of the posterior inferior cerebellar artery for this purpose. Consideration is also given to the vascular changes in herniation of brain tissue through the tentorial notch and the foramen magnum. Our knowledge of the numerous anatomic variations is still incomplete and the reliability of the method is not as high as in encephalography, but out of the 38 cases of verified infratentorial tumours, all but one could be determined and the vast majority localised by vertebral angiography.

ZUSAMMENFASSUNG

Die Grundzüge der Technik für die perkutane Vertebralisangiographie, die in der Röntgenabteilung von Serafimerlasarettet in Stockholm in den beiden letzten Jahren benutzt worden ist, werden beschrieben. Die Ergebnisse in den 150 Fällen scheinen mit denen der Kathetermethode vergleichbar zu sein. Die perkutane Methode scheint ausserdem gewisse Vorteile zu haben und es muss daher als im hohen Grade berechtigt angesehen werden, diese Methode in erster Hand zu benutzen. Es wurde 35 % Umbradil benutzt; nur einmal trat eine kleinere zerebrale Komplikation ein und keinerlei permanente Schädigungen wurden registriert.

Ein kurzer Überblick über das gesamte Material von 250 Fällen wird gegeben. Besondere Aufmerksamkeit wird auf die Möglichkeit, auch gering durchblutete expansive Prozesse in der hinteren Schädelgrube zu lokalisieren sowie auf die Bedeutung der Arteria cerebelli posterior inferior zu diesem Zwecke gerichtet. Beachtung wird auch den Gefässveränderungen in Hernien des Hirngewebes durch die Inzisur des Tentorium und durch das Foramen magnum geschenkt.

Unsere Kenntnis der zahlreichen anatomischen Variationen ist noch immer unvollständig und die Zuverlässigkeit der Methode nicht so gut wie die der Enzephalographie, aber von den 38 verifiierten intratentoriellen Tumoren konnten alle mit Ausnahme von einem festgestellt und die allermeisten durch die Vertebralisangiographie lokalisiert werden.

RÉSUMÉ

L'auteur décrit dans ses grandes lignes la technique employée pour l'angiographie vertébrale percutanée dans le Service de Radiologie de Serafimerlasarettet, Stockholm, au cours des deux dernières années. Les résultats, sur 150 cas, semblent comparables à ceux de l'angiographie par cathétérisme. La méthode percutanée présente en outre certains avantages et doit être, à très juste titre, considérée comme la méthode de choix. Grâce à l'emploi de l'Umbradil à 35 % il n'y a eu qu'une fois une complication cérébrale mineure et on n'a pas observé de lésion permanente.

L'ensemble des 250 cas examinés est rapidement passé en revue. L'auteur a étudié avec une attention particulière la possibilité de localiser des tumeurs, même peu vascularisées, de la fosse postérieure et l'importance de l'artère cérébelleuse postéro-inférieure pour cette localisation. Il a aussi étudié les signes vasculaires de la herniation du tissu cérébral à travers le foramen ovale de Pacchioni et à travers le trou occipital. Nous ne connaissons encore qu'incomplètement les nombreuses variations anatomiques et cette méthode n'est pas aussi sure que l'encéphalographie; cependant, sur les 38 cas vérifiés de tumeurs sous-tentorielles, toutes sauf une ont pu être détectées, et, en grande majorité, localisées par l'angiographie vertébrale.

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LABORATOIRE DE NEURORADIOLOGIE DU SERVICE DE NEUROCHIRURGIE (DIRECTEUR: PROF. AGR. MARCEL DAVID), L'HÔPITAL ST. ANNE, PARIS, FRANCE

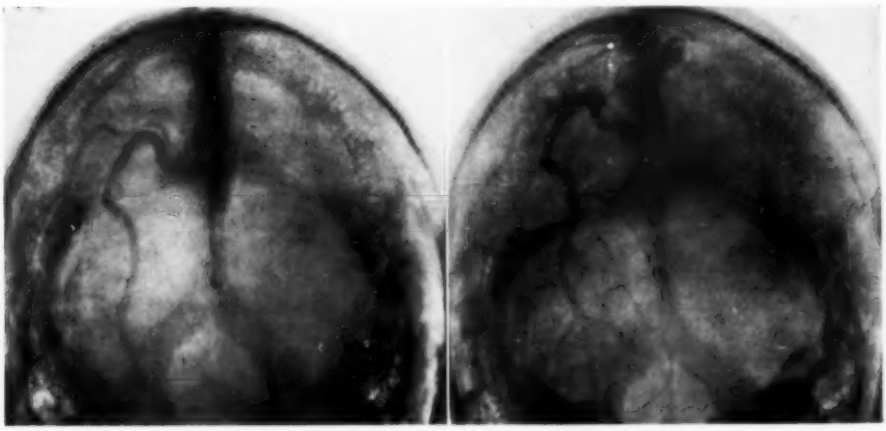
DIRECT OPACIFYING INJECTIONS INTO THE VENOUS SYSTEM OF THE HEAD

by

H. Fischgold, M. David, J. Talairach and *P. Bregeat*

The intracranial veins may be filled with a contrast medium in various ways: either indirectly by means of carotid or vertebral angiography or directly when the contrast medium is injected into the venous system. The latter method has been evolved in the Neurosurgic Centre of St. Anne, Paris under the direction of Professor DAVID.

I. In carotid angiography the veins and sinuses of the brain are filled with contrast medium 2—4 seconds after the beginning of the injection.



a. b.

Fig. 1 a and b. Venous phase of carotid angiography. a) Without, b) with, compression of the jugular veins in the neck. The superficial veins and the sinuses, especially the lateral sinuses, are contrast-filled better in *b* than in *a*.

Fig. 2. Direct sinusography in the direction of the blood stream. Injection at the level of the coronal suture. Compression of the jugular veins. Contrast filling of the superior sagittal sinus, torcular Herophili, lateral sinuses, the upper bulb of the internal jugular veins and the posterior occiput sinus.

The opacification lasts for 3—4 seconds and ends 5—12 seconds after the beginning of the injection (SCHURR and WICKBOM). A complete investigation of the cerebral circulation is obtained only by rapid serial angiography (CURTIS et al.). The veins are however, usually well demonstrated as a routine even if only a few films are taken at 1—2 seconds interval during the circulation of the contrast medium. The density of the contrast medium in the veins is increased if the jugular veins in the neck are compressed. The result is however, inconstant and this method can only be used without danger if the intravenous pressure is constantly checked.

Fig. 3. Direct sinusography (against the blood stream). Contrast injection at the level of the coronal suture. a) Contrast filling of the pterygoid and occipital plexuses in a case with a probable clivus chordoma. b) Later stage. Contrast filling of the external and internal jugular veins.

We obtain good visualization of the veins at St. Anne Hospital by means of a simple film changer, allowing six views to be obtained within 6—8 seconds (both a. p. and lateral views). With this technique the veins and sinuses of the brain are filled with contrast medium in the last three films.

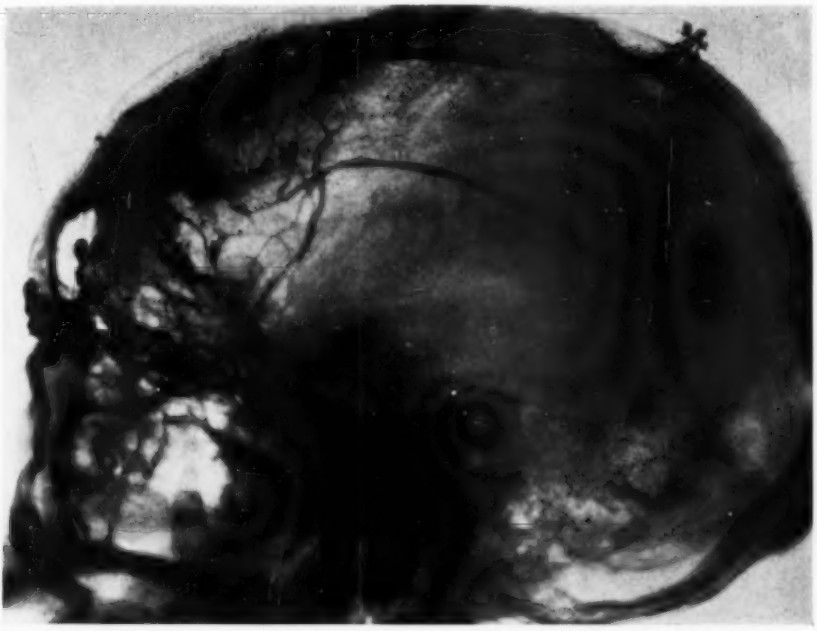


Fig. 4. Direct anterior sinusography. Contrast filling of anterior veins, the inferior sagittal sinus, and one wide facial vein (case of acromegaly).

Recently several authors have stressed the importance of the study of all the vessels of the brain — the veins as well as the arteries. (MONIZ, LORENZ, KRAYENBÜHL, and UMBOCH). With this indirect phlebography the superficial, the deep cerebral veins and the sinuses may be demonstrated in normal cases. All these veins are drained by the internal jugular veins; in addition a part of the meningeal veins is filled with the contrast medium. When using this method the contrast agent follows the direction of the blood stream and thus runs from the intracranial space to the outside of the skull. The eye, however, forms the one exception. The choroid plexus of the eye may often be demonstrated by carotid angiography. The venous blood from the eye runs from the orbit intracranially to the cavernous sinus. In two-thirds of the cases most of the blood (78 %) in the carotid artery passes through the vessels of the homolateral hemisphere. Most of the 'contrast-mixed' blood thus passes through the internal jugular veins on the injected side.

With the indirect method the diploic veins, veins of the scalp, pterygoid plexus, occipital plexus, tributaries of the external and posterior

Fig. 5. Falcotentoriography. Falx cerebri and tentorium cerebelli opacified. The contrast medium has passed from the superior sagittal sinus into the inferior sagittal sinus, straight sinus and lateral sinus.

jugular veins cannot be demonstrated in normal cases and for the examination of this venous system the contrast medium must be injected directly into the veins. This is possible in the case of the superior sagittal sinus, the ophthalmic vein and the diploic veins. The contrast may be injected either in the same or opposite direction as the blood stream. In the latter case the contrast medium must be injected under high pressure. A closer study of the variations in the pressure of the blood during angiography and direct phlebography against the blood stream has not yet been performed.

II. *Direct sinusography without high pressure.*

This method has been recommended by FRENCKNER (1937) in otology, SCOTT in pediatrics and RAY, HOWARD and DOTTER (1951) in neurosur-

a.

b.

Fig. 6. Falcotentoriography. a) in a case of cerebral axis tumour above the tentorium cerebelli. The medial margin of the tentorium is pressed downwards and the tentorium is more horizontal than normally. b) tentorium displaced upwards in a case of cerebellar hemangioma.

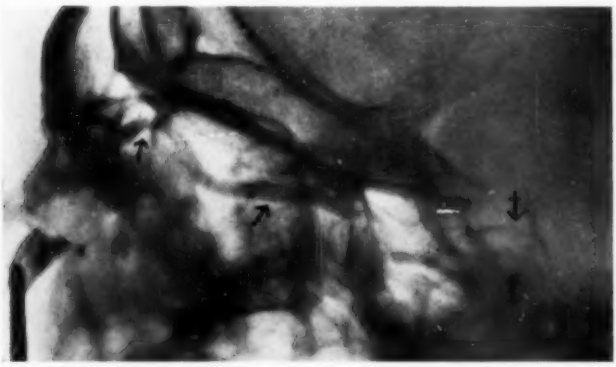


Fig. 7. Contrast filling of ophthalmic vein (←) and the cavernous sinus. The carotid artery is outlined by the contrast medium in the sinus (↔).

gery. These authors recommend the injection of the contrast medium into the superior sagittal sinus, after trepanation, in the same direction as the blood stream without employing high pressure. This method of opacification of the sinus has proved to be of value in phlebitis of the lateral sinus and in meningeoma with extension to the sagittal sinus. The veins demonstrable with this method may also be seen filled with contrast medium by carotid angiography in the venous phase, especially after compression of the jugular veins. The direct injection in the sagittal sinus gives a denser contrast in the veins, but otherwise the results of this method do not differ from those obtained by carotid angiography. Direct sinusography is not in our experience dangerous but its applications remain limited.

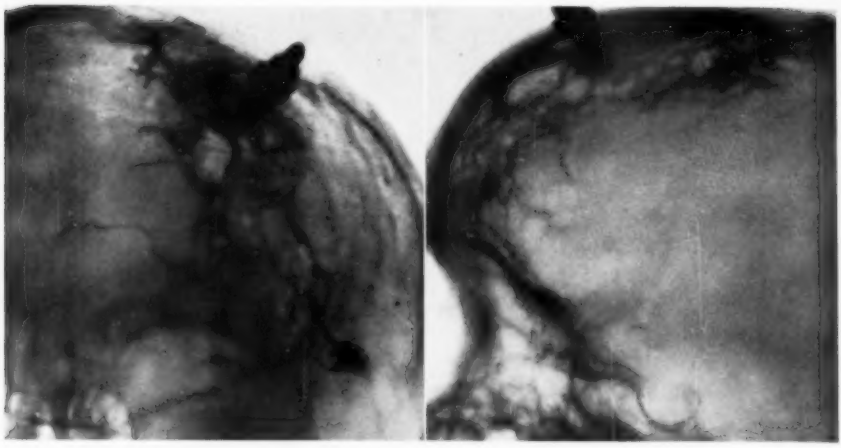
III. *Direct sinusography against the blood stream with high pressure.*

The contrast medium may be injected directly into the anterior part of the superior sagittal sinus above the foramen caecum or at the coronal suture. The contrast agent is injected with high pressure against the blood stream by which method it is possible to fill the anterior venous network and facial veins. These veins are not demonstrable by means of carotid angiography. With the sinusography, collaterals between the circulation of the brain and the facial venous system are demonstrated; we do not, however, know the importance of these collaterals or the part they play in the intracranial pathology.

Fig. 8. Diploëgraphy with contrast injection in the parietal region. Filling of diploic veins passing into a medially situated branch emptying into the occipital plexus.

IV. *Opacification of falx cerebri and tentorium.*

In certain conditions, not yet fully understood, opacification is obtained of the falx cerebri and tentorium cerebelli after contrast injection into the superior sagittal sinus at the level of the coronal suture. (Falcography — tentoriography by TALAIRACH.) As it is possible to obtain such an opacification of the falx and tentorium this must be due to a very dense network in this region. Such a venous system is, however, unrecognised by the anatomists. We have carried out but relatively few such examinations as we have encountered certain complications. Epileptic fits have been observed after the rupture of a vein at the level of the superior sagittal sinus has allowed the contrast medium to leak out into the subarachnoidal space. (The medium was completely absorbed within thirty minutes.) We have also had one fatal accident in a patient with metastasis



a. b.

Fig. 9 a and b. Diploëgraphy in a case of angioma of bone.

from an ovarian tumour. After sinusography, this patient developed epileptic fits followed by coma and death within twenty-four hours; at autopsy there was a considerable oedema of the brain. Until we can employ a contrast medium less irritating than that one we now use (diodone) we do not consider it justifiable to continue these examinations.

V. *Contrast filling of the cavernous sinus.*

The opacification of the cavernous sinus is sometimes obtained in carotid angiography (RIECHERT and KRAYENBÜHL). The contrast density is however, relatively low. We have used another method (BREGEAT and FISCHGOLD), which gives a better contrast filling of the cavernous sinus. Following an incision into the orbit, the contrast medium is injected into the ophthalmic vein in the same direction as the blood stream. In the contrast-filled sinus the carotid artery is seen as a ribbon-like filling defect.

VI. *Diploëgraphy.*

DRASNAR showed in 1936 that it was possible to fill the veins with contrast medium after its intra-osseous injection. The veins of the pelvis are demonstrated after injection into the pubic bone (BAUX and POULHES), the veins of the lower legs after injection into the calcaneum (OLIVIER and LEGER) and the spinal veins after injection into the vertebral apophysis of the spine (FISCHGOLD). In the skull, it is easiest to make the injection

into the occipital protuberance. The injection may be made with or without high pressure. If the diploic bone is thick enough, the trocar may also be inserted into other parts of the skull. In Paget's disease, in which the vault is very thick and soft, an injection in the diploë is performed very easily; the skull in these cases is like a venous sponge, a generalised angioma. If the contrast medium is injected in the occipital region, the occipital diploic veins are contrast filled followed by the veins in the parietal region up to the vertex. The most constant opacification is that of the occipital plexus, which drains into the posterior and external jugular veins and the vertebral veins. It is thus possible to demonstrate the external and posterior jugular venous system by means of diploëgraphy and to demonstrate the anastomosis between the venous circulation of the brain, the meninges, the great sinuses, the vault and the arachnoidian plexuses. The latter plexus may be opacified by direct injection into the spinal apophysis.

Fig. 10. Diploëgraphy in a case of Paget's disease. The diploë is like a generalised angioma and is drained by numerous emissaries into the superficial temporal (I = the middle temporal vein) and the external jugular vein.

Conclusions

Direct phlebography of the skull does not reveal new facts about the cerebral circulation. Contrast media injected into the sinus or diploë are drained to the outside of the skull and not towards the brain and in various pathologic conditions wide venous anastomoses, which in normal subjects are very small, may be demonstrated. There are also collaterals to the external and posterior jugular veins, which, in normal cases cannot be demonstrated. Diploëgraphy shows that the blood supply of the brain only occurs from the carotid and vertebral arteries.

SUMMARY

After a discussion of the opacification of the intracranial veins and sinuses by means of carotid angiography, certain advantages of their direct injection are pointed out. Direct sinusography with and without high pressure, injection of the ophthalmic vein via the orbit and diploëgraphy are described and discussed.

ZUSAMMENFASSUNG

Nach einer Diskussion der Undurchsichtigkeit der intrakraniellen Venen und Sinus durch die Karotisangiographie werden gewisse Vorteile der direkten Injektion in die Venen hervorgehoben. Direkte Sinusographie mit oder ohne hohen Druck, Injektion der Vena ophthalmica durch die Orbita hindurch sowie die Diploëgraphie werden beschrieben und diskutiert.

RÉSUMÉ

Après discussion de l'opacification des veines intracraniennes et des sinus par l'angiographie carotidienne, on montre l'intérêt des injections directes veineuses. La sinusographie directe, l'opacification du sinus caverneux par voie orbitaire et la diploëgraphie sont discutées.

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FROM THE DEPARTMENT OF ROENTGENOLOGY AND RADIUMTHERAPY (DIRECTOR: PROFESSOR M. SMOKVINA) AND THE NEUROSURGICAL DIVISION (DIRECTOR: D. RIESSNER), OF THE MEDICAL SCHOOL OF THE UNIVERSITY OF ZAGREB, ZAGREB, YUGOSLAVIA

ANGIOGRAPHIC STUDIES IN THE PROBLEM OF BRAIN REVASCULARIZATION

by

V. Gvozdanović and *D. Riessner*

Introduction

The problem of revascularization of the brain lies in a domain which, so far, has shown but slight progress. And yet, its extraordinary importance cannot be denied. Mental retardation and epilepsy are frequently the sequelae to damaged neurons due to malnutrition and, above all, to hypoxemia, of which trauma, inflammation and vascular diseases, constitute the chief causes.

Beck's Operation

By the revascularization of the damaged areas it should be possible to produce favourable conditions for the damaged neurons to be rehabilitated or regenerated, and the pathologic symptoms to disappear. For this purpose BECK and his co-workers in 1949, suggested the production of a fistula between the right common carotid artery and the right internal jugular vein.

The principles upon which their operation was based are as follows:

1) There are numerous anastomoses between arteries and veins in the brain, and the authors felt that the 'arterial blood under arterial pressure in the venous system would result in a redistribution of the blood flow'.

2) The superior sagittal sinus is continuous with the right transverse sinus, while the straight sinus is continuous with the left transverse sinus. There are numerous anastomoses in existence between the superficial and deep veins of the brain. BECK and his co-workers therefore

held that the 'operation upon the right side would contribute the majority of blood to the cortex, and also significant amounts to the deep circulation'.

3) The above authors do not believe in the danger of overburdening the right side of the heart due to an arterio-venous shunt, 'because the internal jugular vein proximal to the anastomosis is tied off'.

BECK and co-workers attempted to ascertain the effect of the procedure by injecting radioactive iodine prior, as well as subsequent to operation, by measuring the irradiation in the region of one hemisphere by means of a Geiger counter, as well as by checking the difference of oxygen in the veins and arteries. They came to the conclusion that the operation had strengthened the circulation in the brain. They wrote: 'We believe this procedure represents the first successful attempt at correction of mental retardation on an organic basis.'

Some Problems in Connection with Beck's Operation

The optimism displayed by BECK and his co-workers was an impetus for us to apply their method in fifteen cases. In so doing we also attempted an angiographic analysis of the principles and results of the method. The first angiographies were carried out in the middle of 1951. The experiences gained in the work constituted the basis upon which this paper was framed.

We deemed it necessary to answer the following questions:

1) Is there really such a prominent domination of the right transverse sinus over the left which would justify the routine application of the fistula on the right side? Is there any possibility of establishing preoperatively the relationship between the calibre of the right and the left transverse sinuses?

2) What happens to the arterial blood when it enters the internal jugular vein through the fistula?

3) Is it possible to ascertain anything pre-operatively about the probable effect of the operation?

4) In which direction is the venous blood drained from the surface of the brain when the right jugular vein is tied off?

Anatomy of the Region Examined

Before presenting the results of our investigation it will be necessary to say something about the venous system of the brain. As one of us (G) has been studying the normal phlebogram for a considerable period, we shall also mention a few results of this study.

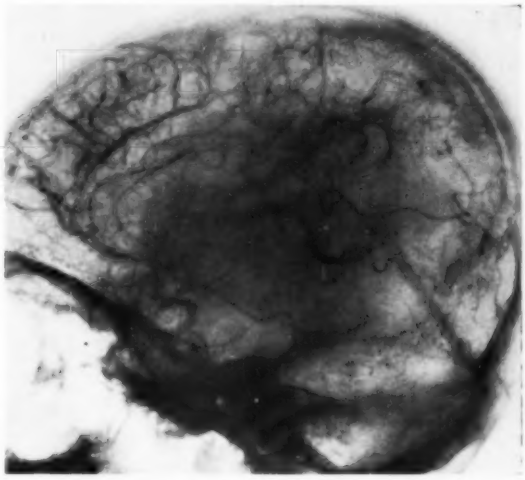


Fig. 1. Carotid angiography: Internal cerebral vein and the straight sinus in arterial phase.

In the brain there are deep and superficial veins and sinuses. The system of the deep veins and sinuses, as one of us (G) established as early as 1948 on a material of Serafimerlasarettet, fills very early in angiographic procedures; this may sometimes occur at the end of the arterial phase (Fig. 1), usually prior to the superficial veins or simultaneously with them, but never after them as was believed earlier.

The *superficial veins* represent a network of anastomoses within which we may often identify individually characteristic and fairly constant veins. Thus, for instance, the majority of blood is often drained towards the convexity by the vein of Trolard, a vein that connects the region of the middle cerebral vein with the superior sagittal sinus and is usually situated in the region of the central sulcus or a little more backwards (Fig. 2). The vein of Labbé connects the region of the middle cerebral vein with the transverse or superior petrous sinus (Fig. 3). The vein which has been neglected most in roentgenology and which is the most constant of all the superficial veins in position, is the middle cerebral vein; it lies in the Sylvian fissure, winds round the anterior pole of the temporal lobe and enters the cavernous sinus (Fig. 4). Anastomoses between the middle cerebral vein and the vein of Trolard or that of Labbé produce the characteristic picture of a 'diagonal' or 'arch'.

Each of the veins mentioned is capable of assuming the greater part of the drainage of the convexity, as sometimes shown in a phlebogram (Figs. 2—4). No superficial vein possesses valves, the circulation in the veins thus being possible in all directions.

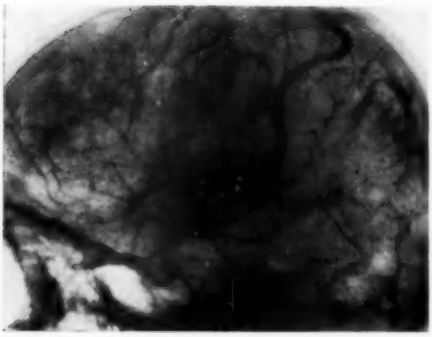


Fig. 2.

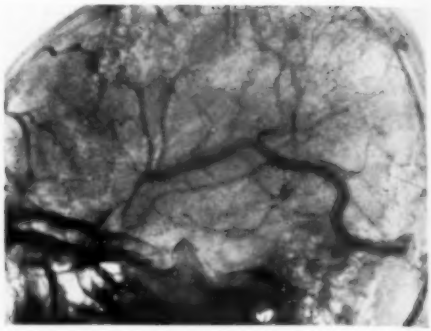


Fig. 3.

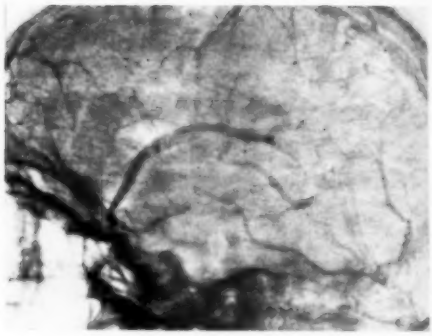
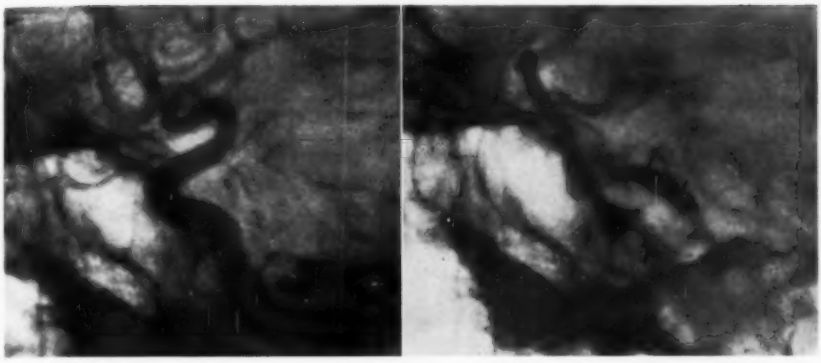


Fig. 4.

Fig. 2. Well-marked vein of Trolard.
Fig. 3. Well-marked vein of Labbé.
Fig. 4. Well-marked middle cerebral vein.

The anastomoses between the vein of Trolard or Labbé, with the middle cerebral vein entering the cavernous sinus, permit drainage of the surface of the brain towards the cavernous sinus. When the cavernous sinus is well filled with contrast medium it will display a bright line that corresponds to the inner carotid artery, which, at that moment, contains no contrast. This — 'the phenomenon of the negative shadow of the internal carotid' — was named and described by one of us (G) in 1948. (Figs. 5 a—b.) The cavernous sinus is in communication, via the ophthalmic veins, with the veins of the face, and by the way of the superior and inferior petrous sinuses with the transverse sinus or with the internal jugular vein. By the veins of Labbé and Trolard it is connected via the middle cerebral vein with the transverse or the superior sagittal sinus. The rete venosum foraminis ovalis and the plexus venosus caroticus int. connect the cavernous sinus with the pterygoid plexus, while the petro-occipital sinus represents a link with the plexuses of the



a. b.

Fig. 5. a. The inner carotid artery in the region of the sella turcica. b. A bright line in the well-filled cavernous sinus — 'the phenomenon of the negative shadow of the internal carotid' — the venous phase of 5 a.

pharynx. In the basal plexus we have undoubtedly the most important anastomosis; it lies between both inferior petrous sinuses, and via the occipital plexus connects the cavernous sinus with the venous plexuses of the spine (plex. ven. vertebrales externi et interni). By the way of the sphenoparietal sinus, the cavernous sinus is in communication with the meningeal and diploic veins.

For the problems of revascularization of the brain by means of an arterio-venous fistula between the right carotid artery and the right internal jugular vein, the anatomy of the confluens sinuum is the central point of interest. If the right transverse sinus really represents a direct continuation of the superior sagittal sinus, as supposed by BECK, the arterial blood introduced into the right internal jugular vein would have to reach the superficial veins of the convexity by the same pathway. According to European anatomic textbooks and our phlebographic experiences, the classical form of the confluens sinuum as a common cavity in which the superior sagittal sinus, straight sinus, occipital sinus and both transverse sinuses meet, is extremely infrequent. In the most common form, the superior sagittal sinus and the straight sinus each ramify over the protuberance into two branches of which usually the right branch of the superior sagittal sinus and the left branch of the straight sinus are larger (Fig. 6). Thus, in place of the confluens sinuum, we may find in the region of the protuberance the triangular field of the dura, and which occasionally appears as an island if both transverse sinuses are connected by a transverse canal. Cases in which the superior sagittal sinus possesses only a single continuation into the right or left

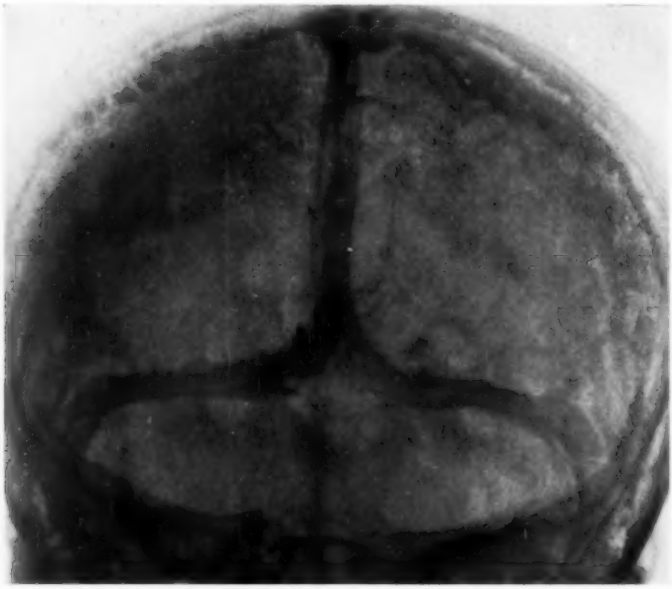


Fig. 6. The ramification of the superior sagittal and straight sinuses over the protuberance.

transverse sinus, represents only one, not too common, variation of the type.

The occipital sinus, which connects the region of the confluens sinuum with that of the great occipital foramen, remains to be mentioned (Fig. 7). It divides along the ridge of the foramen into two limbs or marginal sinuses, which communicate with the caudal portion of the sigmoid sinus and with the occipital plexus or internal vertebral plexuses. Around the occipital foramen, they form a venous bridge which connects both sigmoid sinuses. We have succeeded in visualizing this sinus in certain cases by retrograde phlebography of the internal jugular vein and in identifying it in a normal phlebogram (Figs. 8 a—b) — a procedure, to our knowledge, not previously described.

For the problems under discussion, two emissary veins are of great importance: the condyloideum (Fig. 9) and the mastoideum (Fig. 10 a—b), of which the latter is not infrequently of the thickness of a lead pencil. These emissaries connect the sigmoid sinus with the occipital or vertebral vein, into which the rete venosum canalis n. hypoglossi also finds its way.

The anastomoses between the superficial and deep veins, which in BECK's method, should play an important rôle, are considered by the

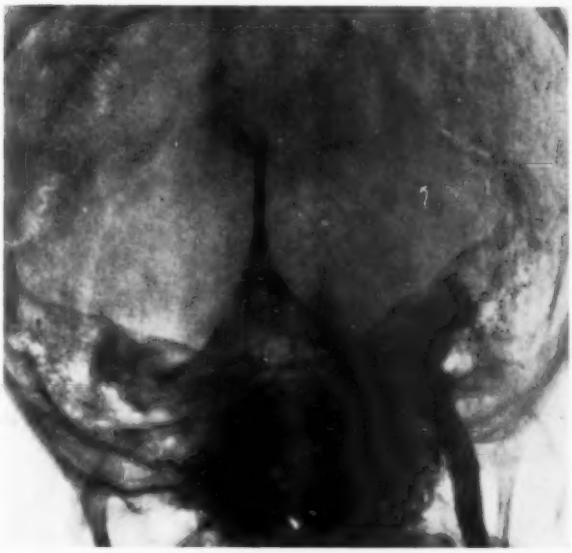
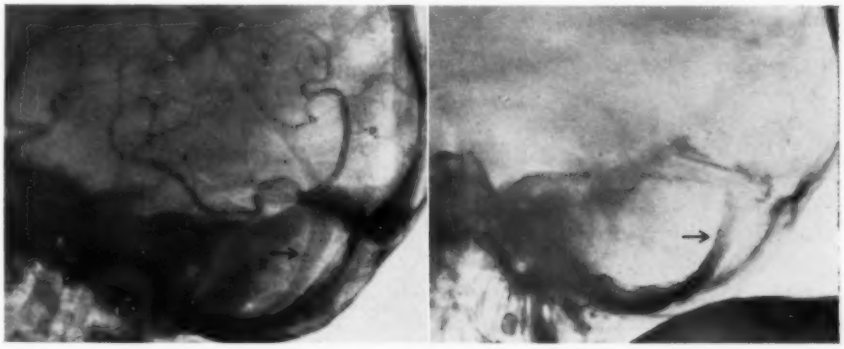


Fig. 7. The occipital sinus and marginal sinuses visualized by retrograde phlebography of the internal jugular vein.

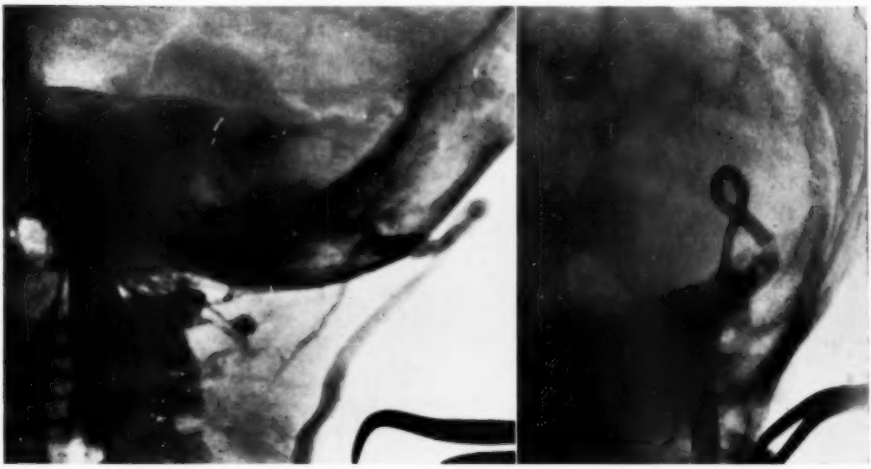


a. b.

Fig. 8. a. Normal angiography of the internal carotid artery, venous phase, lateral: the occipital sinus. b. Retrograde phlebogram, in the same patient, lateral: the occipital sinus.

majority of authors to be unimportant owing to their small calibre, while the arterio-venous communications are regarded as being fairly infrequent and of no great import in the matter of circulation.

Fig. 9. The medium escaping through the emissarium condyloideum in the plexuses of the neck (retrograde phlebography).



a. b.

Fig. 10. a. Retrograde phlebography: The medium flowing into the plexuses of the occiput through the emissarium mastoideum. b. The emissarium mastoideum in half-axial projection.

Material

Our material comprises sixteen patients — children between 2 and 12 years of age with various degrees of mental retardation and epileptic fits, as a consequence of trauma at birth or encephalomeningitis. Eight boys and seven girls were operated upon. In one case, only angiographic examinations were performed, as the poor conditions for revascularization made us abstain from undertaking the production of a fistula.

Method

For the purposes of the angiographic analysis of BECK's principles and the results of his method, we have, for a year or so been using the following technique in each case destined for operation:

Serial angiography with four exposures, both lateral and semi-axial projection being included. The contrast medium consists of Umbradil 35 %, of which 10—20 ml are injected.

The right common carotid artery is exposed and serial angiography carried out for the purpose of ascertaining which of the transverse sinuses is more developed, and thus theoretically more suitable for the fistula formation.

In this way, however, it is impossible always to establish the quantity of blood the individual transverse sinus receives from the superior sagittal sinus, and from the straight sinus. As regards the superior sagittal sinus this would be possible to ascertain only by means of sinusography, a procedure which we have not considered as being indicated. Practically, it suffices if a determination is made as to which of the transverse sinuses is better developed, for it is beyond doubt that this will contain at least part of the blood from the superior sagittal sinus; fifteen examinations in eleven patients were performed in this way.

The determination completed, a temporary ligature of the right internal jugular vein is made below the site of the intended fistula, and 20 ml of contrast medium is injected into the vein at maximum pressure within 1—2 seconds. Prior to this, all the branches of the internal jugular vein above the site destined for the fistula will have been tied off as high as the base of skull — according to BECK — lest the dye should invade the facial veins and those of the neck, instead of the sinuses. The first film is made during the injection, while the others are obtained at intervals of one second.

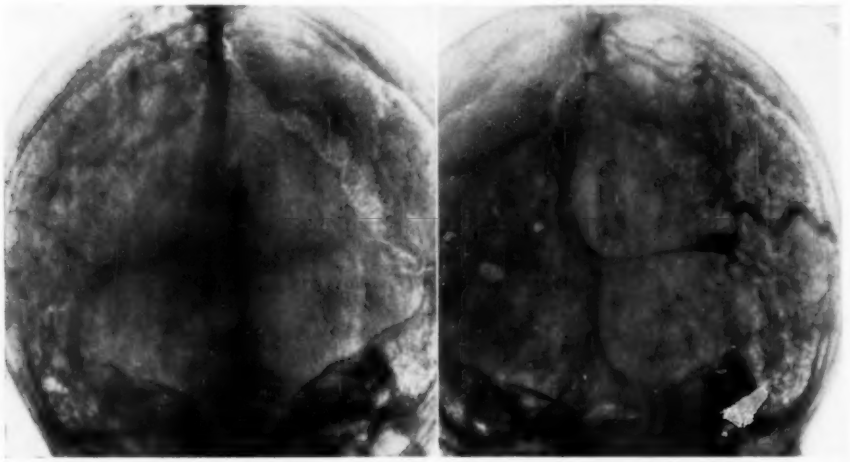
In employing the technique of retrograde phlebography, we tried to imitate conditions following the tying off of the internal jugular vein and the production of the fistula. It was our intention to discover the post-operative pathway of the arterial blood after entering the internal

jugular vein through the fistula. The procedure described was used twelve times in nine patients.

In all cases in which the conditions for an operation on the right side meet the minimum requirements, a fistula (BECK) is made during the same session. If the conditions are unfavourable, the same examination is performed on the left side at a second session. The operation having been performed, serial angiography is carried out forthwith by injecting 20 ml of contrast medium into the common carotid artery somewhat below the fistula itself. We have performed, to date, nine angiographic control tests immediately subsequent to the production of the fistula and two, four to six months after operation.

Results

The results obtained by the study of the transverse sinuses in the half-axial films of the phlebographic phase of serial angiography of the carotid artery, correspond to those obtained by RAY and his co-workers with the aid of sinusography. Usually both transverse sinuses fill; the right was frequently more prominent than the left. In only two out of eleven patients was the left transverse sinus more prominent than the



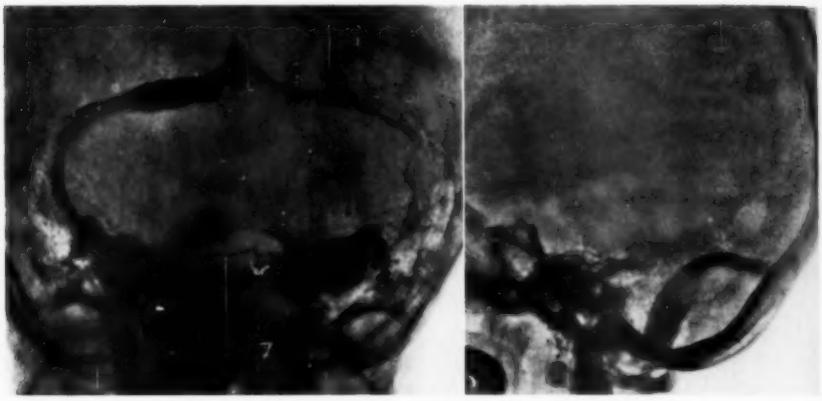
a. b.

Fig. 11. a. Broad right transverse sinus, the left very weak. b. Angiography of the left internal carotid artery in the same patient, venous phase: a broad vein of Labbé conveys the majority of the blood from the dorsal part of the left convexity directly into the distal portion of the left transverse sinus. Fine communication with the confluens sinuum and the occipital sinus.

Fig. 12. Retrograde phlebography: Cavernous sinus and the plexuses of pharynx.

right, and in one case both were equal in size. If one transverse sinus is either very slender or missing altogether, we may find a prominent occipital sinus or a broad vein of Labbé, which convey the major part of the venous blood from the back of the convexity of the side involved directly into the distal portion of the transverse sinus (Fig. 11 a—b).

The results of the retrograde phlebographic examinations were more than discouraging. In six cases, the contrast medium hardly reached the caudal portion of the sigmoid sinus; it did not proceed farther upwards but, by way of the emissarium mastoideum (Fig. 10), the condyloideum (Fig. 9) and the rete venosum canalis n. hypoglossi, it flowed into the plexuses of the neck and occiput. A less amount of the medium flowed through the inferior petrous sinus into the cavernous sinus, from which it went into the pharyngeal veins by way of the pterygoid plexus or into the vertebral venous plexuses by way of the basal plexus (Fig. 12). In only three cases did the contrast medium reach the confluens sinuum by way of the transverse sinus (Figs. 13 & 14 a & b); in so doing, it partly invaded the transverse sinus of the opposite side and descended through the opposite internal jugular vein and partly returned upwards on the same side and was drained by the emissaries and the communications



a. b.

Fig. 13. a. Retrograde phlebography: The contrast medium reaches the confluens sinuum and invades the transverse sinus of the opposite side. b. Lateral view.

mentioned into the veins of the neck, occiput, pharynx and spine. In those cases in which the contrast medium was identified as high as the confluens sinuum, there was always a communication between the right and the left transverse sinuses; this enabled the contrast medium to choose the pathway of less resistance, *i. e.* to take the direction of the venous blood flow, or, in other words, that of the opposite transverse sinus, instead of flowing against the blood-stream into the straight and superior sagittal sinus. This fact is at once evidence that the systems of drainage of the straight sinus and the superior sagittal sinus are not divided as is assumed in BECK's method, but that in the majority of cases a communication in the region of the confluens sinuum exists between both transverse sinuses and both systems mentioned.

In two cases of retrograde phlebography of the internal jugular vein, filling of the occipital sinus occurred (Figs. 7, 8 b). In these instances the contrast medium filled up the marginal sinuses, and while a portion of it descended into the venous plexuses of the vertebrae and into the internal jugular vein of the opposite side, another part reached the confluens sinuum. In one of these cases, a small part of the medium invaded the transverse sinus.

As has been stated, in no case of the twelve retrograde phlebographies of the ligated internal jugular vein did the contrast medium enter the superior sagittal sinus, the straight sinus or the superficial veins.

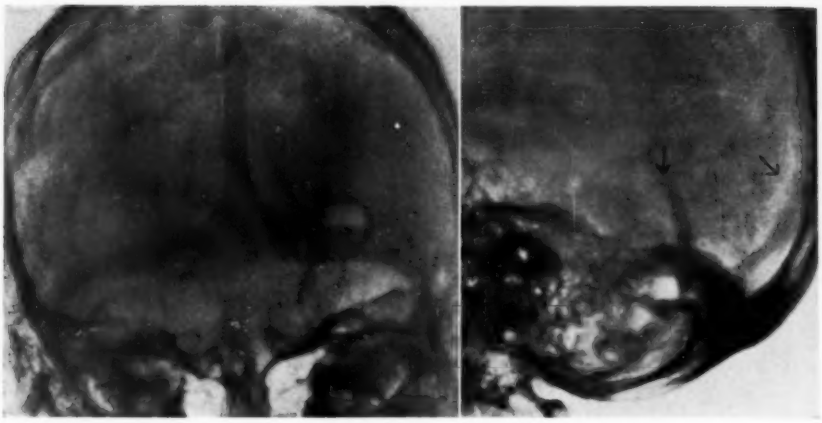
The results of angiographies made after the production of the fistula may be summarized as follows. In four cases, by injecting the dye into

a. b.

c.

Fig. 14. a. The medium injected in the left internal jugular vein reaches the confluens sinuum and invades the right transverse sinus which is much narrower than the left. b. Lateral view. c. Immediately after the production of the fistula — simultaneous filling of the inner carotid artery and the internal jugular vein.

the common carotid artery, a retrograde phlebogram of the internal jugular vein was obtained simultaneously with an arteriogram of the common carotid artery (Fig. 14 c); the phlebogram was more pronounced on two occasions. Three times, a phlebogram was the almost exclusive



a. b.

Fig. 15. a. Same patient as fig. 14, four months after operation — the medium enters the superior sagittal and the straight sinus. b. Lateral view.

result. On three occasions, the whole of the contrast medium invaded the branches of the common carotid artery; in one of these cases thrombosis of the internal jugular vein was present, which had developed after the operation, while in two cases the point of the needle seemed to have been above the level of the fistula.

We especially appreciate the importance of the fact, that in all the cases in which the internal jugular vein filled well with the contrast medium after production of the fistula, the results were identical to those obtained by means of retrograde injecting of the medium pre-operatively (Fig. 14 a—c).

Thus the accuracy of retrograde phlebography of the internal jugular vein as a pre-operative method of investigation of the suitability for operation was corroborated. In no case did the arterial blood containing the contrast medium enter the superior sagittal sinus, the straight sinus or the superficial veins immediately after the operation.

In only one of two cases in which angiography was performed as long as four months after operation, was the contrast medium observed to enter the superior sagittal sinus and the straight sinus to distances of about 5 cm, while before operation, this could not be observed (Figs. 14—15). The majority of the contrast medium, however, was seen in this case also to invade the transverse sinus of the opposite side. This was the case which compelled us to close the fistula owing to marked deterioration of the condition of the patient in spite of the excellent

function of the fistula; the symptoms were epileptic fits at more frequent intervals, marked occipital headache, pronounced apathy and unbearable cerebral pulsations.

At the Third Symposium Neuroradiologicum, in the discussion following our paper, H. LARSSON gave his own experiences in this field. Though he had used a different technique of examination, his final results were comparable to ours.

From verbal communications from E. WALKER and J. I. POPPEN received by one of us (R) during his stay in the United States in the autumn of 1952, it would appear that the enthusiasm for this method of operation has subsided over there owing to experiences similar to ours.

Conclusions

The hemodynamic conditions for the revascularization of the brain with the aid of BECK's fistula appear to be most unfavourable. It is possible to ascertain them fairly accurately by preoperative retrograde phlebography.

After the production of the fistula, the arterial blood enters neither the cortex nor the deep veins of the brain, but under pressure of the venous blood coming by way of the superior sagittal sinus and straight sinus, it is expelled through the transverse sinus of the opposite side, and emissaries, sinuses and plexuses in the base of the skull into the veins of the neck, occiput, pharynx and spine.

The circulation in the brain is, therefore, not only not improved by the fistula, but a substantial portion of arterial blood is shunted over to the descending veins of the neck, thus considerably reducing the flow of arterial blood into the brain. As a consequence, overburdening of the right side of the heart may be expected to occur.

We hold the opinion that, from a purely angiographic viewpoint, BECK's operation should be limited only to those cases in which preoperative retrograde phlebographies have shown good filling of the superior sagittal and straight sinuses. Thus far, such cases have not been met with.

It is our opinion that the angiographic analysis of the principles and results of BECK's operation gives a fairly good explanation of the fact that of the fifteen fistulas performed, in no case could substantial clinical improvement be observed.

Thus by means of the above-mentioned procedure we have been unable to confirm that BECK's method offers a possibility of brain revascularization possessing practical value.

SUMMARY

The paper aims at representing an angiographic analysis of Beck's operation. The authors show that after the fistula has been produced the arterial blood enters neither the cortex nor the deep veins of the brain, but that under the pressure of venous blood

coming by the superior sagittal sinus and straight sinus, is expelled via the transverse sinus of the opposite side, and through emissaries, sinuses and plexuses of the same side into the veins of the neck, occiput, pharynx and spine. Retrograde phlebography of the inner jugular vein proves that the hemodynamic conditions in the region of this vein are unfavourable for the purpose of revascularization.

ZUSAMMENFASSUNG

Der Artikel dient zur Repräsentation einer angiographischen Analyse von Beck's Operation. Die Verf. zeigen, dass das arterielle Blut nach Anlegung der Fistel weder in die Cortex noch in die tiefen Gehirnvenen eindringt, sondern dass es unter dem Druck des venösen Blutes, welches von Sinus sagittalis superior und dem Sinus rectus kommt, über den Sinus transversus der Gegenseite, und durch Emissarien, Sinus und Plexus der gleichen Seite in die Venen des Nacken, des Okziput, des Pharynx und der Wirbelsäule hineingetrieben wird. Retrograde Phlebographie der Vena jugularis interna bekräftigt, dass die hämodynamischen Bedingungen im Gebiet dieser Vene für die Revaskularisierung ungünstig sind.

RÉSUMÉ

L'article a pour but de présenter une étude angiographique de l'opération de Beck. Les auteurs montrent qu'après la création de la fistule le sang artériel ne pénètre ni dans le cortex ni dans les veines profondes du cerveau mais que, sous la pression du sang veineux venant du sinus longitudinal supérieur et du sinus droit, il est chassé à travers le sinus latéral du côté opposé, et par les émissaires, les sinus et les plexus du même côté dans les veines du cou, de l'occiput, du pharynx et du rachis. La phlébographie rétrograde de la veine jugulaire interne prouve que les conditions hémodynamiques dans le territoire de cette veine ne se prêtent pas à la revascularisation.

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FROM THE ROENTGEN DEPARTMENT (DIRECTOR: PROFESSOR ERIK LINDGREN),
SERAFIMER LASARETTET, STOCKHOLM, SWEDEN

THE CEREBRAL PHLEBOGRAM BY CAROTID ANGIOGRAPHY IN CASES OF CENTRAL BRAIN TUMOURS

by

Curt Johanson

In this short paper, preliminary to a larger work on the central veins of the brain under normal conditions and in the presence of intracranial expanding processes, only central and centrally infiltrating processes are discussed. In the angiographic literature, interest has mainly been focussed on the displacement of arteries and the existence of pathologic vessels. The position and appearance of the central veins have not often been taken into consideration.

The vascular pattern of the brain in general is not the same as that of other parts of the body. The arteries and veins of the brain do not run together but have different courses so that the position of the arteries gives information regarding parts of the brain not obtainable from the position of the veins. An expanding lesion may thus influence either the arterial or the venous system or both. For all roentgendiagnosis a thorough knowledge of normal anatomy and its variations is of course necessary. From our experience, the description which the text books of anatomy present of the veins of the brain, is not consistent with the appearances revealed by angiography. The descriptions of the veins in the angiographic literature seem to be based on relatively limited material, of which only a few cases are checked by pneumography to exclude expanding or contracting processes. Some of the anatomic variations of the course of the vessels, and other topographic details, have not been described at all.

Moniz, with the intention of studying the anatomy in cadavers, injected contrast medium into the jugular veins, having ligated the vertebral veins. With this technique the representation of the deep veins is complicated by the superimposition of superficial veins and sinuses

The deep veins have been regarded as difficult to identify in a-p films for the same reason. One projection is, however, not sufficient to gain a clear idea of the exact position of a vessel and to gather whether it is displaced or not. Films in planes at right angles at least are necessary, often supplemented by further projections. In our experience stereoscopic views do not give sufficiently exact localisation. For a detailed examination of the central veins, a study of their appearances in a-p views is necessary.

Method and Material

The following description of the anatomy of the central veins is based on a series of examinations of cadavers. The results have been compared with angiographies of patients in whom the history, clinical symptoms, course of the case and encephalography exclude expanding or atrophic processes. The angiographic technique employed is the one described by LINDGREN.

A hole was burred over the confluens sinuum, a small opening made in the dura and a catheter introduced in the straight sinus; this occluded the hole, thus preventing the contrast medium from flowing backwards into the superficial sinuses and veins.

The contrast medium consisted of barium sulphate in water and gelatine, being easy flowing under warm conditions, solidifying at normal temperatures and hardening in formalin. The method permitted a selective study of the deep veins. The position of the veins was examined in views in different projections. The brain was then removed, together with the dura over the hemispheres, and fixed so that it was not deformed. The findings at the roentgen examination were then checked by dissection. The results from this material were compared with 200 normal angiographies.

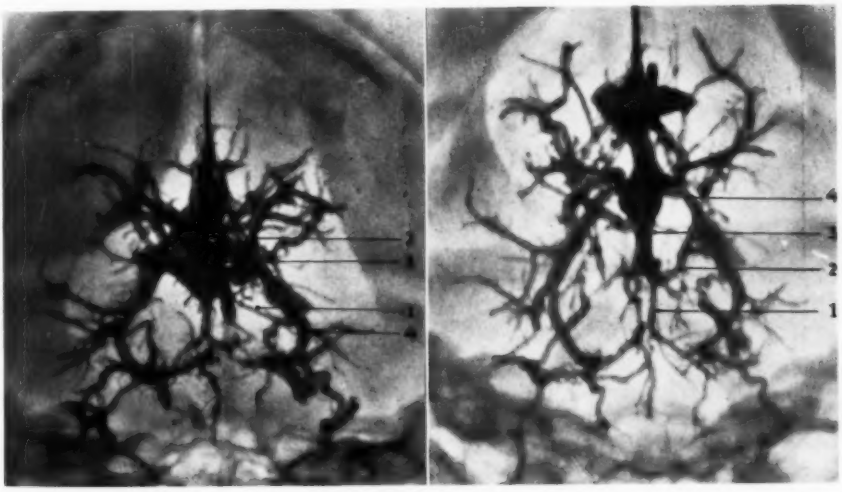
Normal roentgenologic anatomy

Although the arteries and veins do not run together, a certain system in the course of the veins may be recognised.

The *internal cerebral vein* (Fig. 1), which is duplicated, runs along the roof of the third ventricle. It has practically the same course on both sides, passing between the posterior part of the corpus callosum and the pineal corpus, the veins of the right and left sides joining behind the splenium to form the great cerebral vein.

We usually take two series of a-p films: one with the central beam parallel to the floor of the anterior fossa of the skull and another with a half-axial projection (30—35 degrees tilting of the tube cranially).

a.



b. c.

Fig. 1. Autopsy case. Contrast medium injected into the central veins through the straight sinus. a. Lateral view. b. Antero-posterior view. c. Antero-posterior half-axial view. 1. Vein of septum pellucidum. 2. Striothalamic vein. 3. Internal cerebral vein. 4. Basal vein.

Fig. 2. Autopsy specimen. Lateral (above) and full axial view (below). 1. Vein of septum pellucidum. 2. Striothalamic vein. 3. Internal cerebral vein. 4. Basal vein. 5. Vein of posterior horn.

In this view, the internal cerebral vein is mainly reproduced in an axial direction, covered by the superior longitudinal sinus and deep sinuses. It is, however, situated slightly lateral to the midline and may therefore partly be seen and its relation to the midline determined. Vessels which run from the walls of the lateral ventricle are shown. The striothalamic vein is easy to recognise, especially in the half-axial a-p films. It runs in an antero-medial and oblique direction and at its anterior end runs

Fig. 3. Autopsy specimen. The choroid vein has a characteristic spirally twisted course.

Fig. 4. Diagram showing various forms of the curve between the striothalamic vein and the internal cerebral vein.

into the internal cerebral vein, forming a curve, convex anteriorly. Postero-laterally, minute veins run into the striothalamic vein, giving the appearance of a small plume which is easily recognised.

The *basal vein* (Fig. 1) originates in the region of the anterior perforated substance. In lateral views of the skull, this is situated about 1 cm above the sella turcica. The basal vein first runs backwards and follows roughly the same course on both sides. A few centimeters behind its origin it curves away, upwards and backwards, and proceeds medially to the great cerebral vein. The latter part of its course may vary a little on each side.

The basal vein also has a characteristic course in a-p views. The anterior part of the vein is seen slightly above and medial to the internal auditory meatus. Antero-laterally, there are connections with the veins of the Sylvian fissure and medially with veins at the base of the brain and the basal vein of the other side. The basal vein runs medially upwards and backwards towards the great cerebral vein, sometimes fairly straight and sometimes in a curve convex laterally. It is generally situated on the medial border of the temporal lobe.

A lateral displacement is easy to detect in half-axial films because in this projection the central beam is almost at right angles to the main course of the basal vein. The internal cerebral vein collects veins from the tissue in the walls of the lateral ventricles. Some of these veins are fairly large and constant and are easily recognised on angiography (Fig. 2).

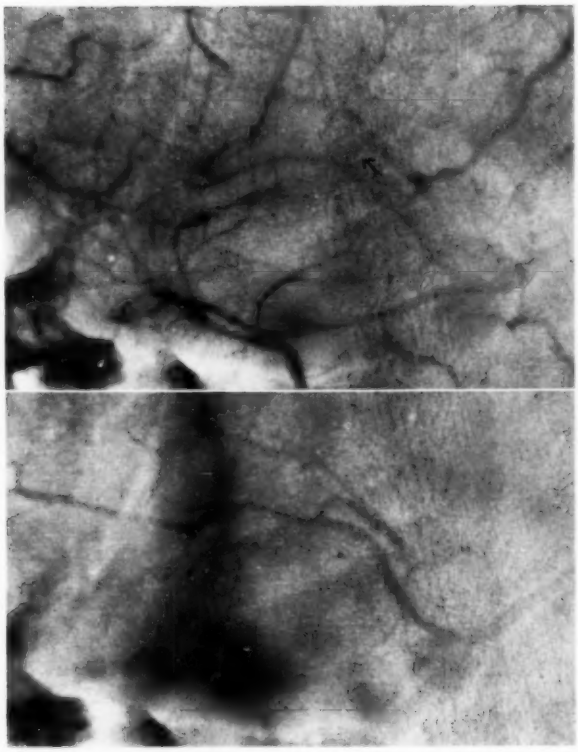


Fig. 5. A vein terminating approximately in the middle of the internal cerebral vein may be confused with the striothalamic vein if the latter is not filled with medium simultaneously (below). This vein and the striothalamic vein filled with contrast above. A moment later no contrast is seen in the striothalamic vein.

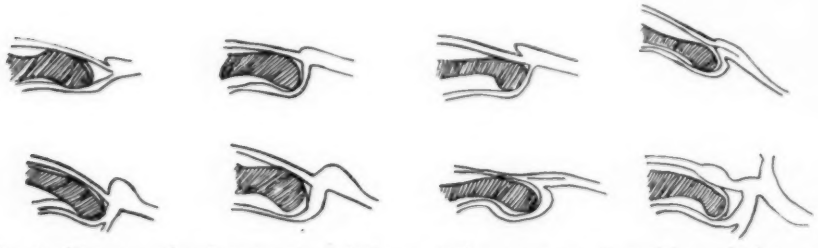


Fig. 6. Diagram showing some variations of the course and position of the great cerebral vein.

a.

b.

Fig. 7. Autopsy specimen. The posterior cerebral vein indicates the position of the splenium. Anomalous course of the inf. long. sinus and anomalous vessel in the falx between the straight sinus and superior long. sinus.

The *vein of the septum pellucidum* arises from the anterior and medial part of the anterior horn and passes backwards along the septum pellucidum. It is usually slightly curved, although it may be quite straight.

The *striothalamic vein* comes from the walls of the middle part of the lateral ventricle and runs along the floor, usually in a curve convex

Fig. 8. Variations in the course of the inferior longitudinal sinus and the straight sinus in normal phlebograms.

anteriorly, passing through the posterior part of the foramen of Monro to join the internal cerebral vein.

Further back the internal cerebral vein receives vessels from the posterior parts of the lateral ventricles.

There is one fairly large constant vein running along the medial wall of the posterior horn. This vein is not mentioned at all in the general anatomic handbooks and roentgenologic literature; for it I suggest the term "vein of the posterior horn".

The *choroid vein* (Fig. 3), arises from the choroid plexus of the lateral ventricle and runs into the striothalamic vein. The choroid vein has a characteristic spirally twisted course.

The form of the curve between the striothalamic vein and the internal cerebral vein may vary a great deal, as Fig. 4 shows. The form with a backward diverging angle may wrongly be regarded as pathologic. In normal cases, the course of the vessel is always smooth and the junctions curved.

A vein terminating approximately in the middle of the internal cerebral vein may be confused with the striothalamic vein. If the striothalamic vein is not filled with contrast simultaneously the appearance may wrongly be interpreted as representing a backward displacement of the foramen of Monro (Fig. 5).

The *great cerebral vein* is generally regarded as having a constant course, curving round the splenium and running forwards into the inferior longitudinal sinus at an acute angle. The curve of this vein is regarded as defining the posterior part of the corpus callosum. In my experience it does not, however, have such a constant course. Sometimes it courses round the splenium, but proceeds off at a tangent from the upper surface and flows into the straight sinus. At other times it runs more or less at a right angle to the straight sinus or practically directly backwards towards the straight sinus. When these last two variations are present the vessel is separated from the splenium to a varying degree (Fig. 6). The splenium may, however, always be lo-

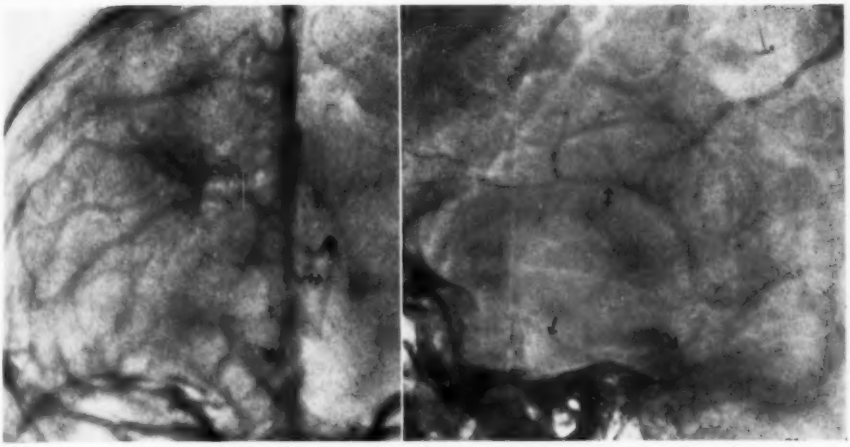


Fig. 9. Case 1. Malignant glioma in the basal ganglia on the right side. The arteriogram shows a hydrocephalus but gives no information of its cause. Pericallosal artery in the midline. On the phlebogram a central expanding process is diagnosed by means of the central veins. The internal cerebral vein (↑) is displaced to the left and, together with the striothalamic vein, raised. The basal vein (↑) is stretched and depressed and its posterior part is displaced to the left.

calised by a small constant double vein which comes from the postero-inferior part of the medial surface of the hemisphere and the posterior part of the corpus callosum, and runs round the splenium into the internal cerebral vein (Fig. 7).

The *inferior longitudinal sinus*, according to the literature, forms a smooth curve in the lower border of the falx. It is therefore closer anteriorly than posteriorly to the vault and runs into the straight sinus. In this material the inferior longitudinal sinus also formed a smooth curve in the majority of cases. Exceptions are, however, not unusual and the sinus may in certain cases have a more or less straight course. Such an appearance is not pathologic. Even the course of the *straight sinus* may vary. It may either run quite straight or in a shallow curve, convex or concave, upwards or downwards (Fig. 8).

Venous Changes in Central Tumours

Central tumours influence the position of the deep veins also in cases in which no evident displacement of the arteries can be demonstrated. All the following cases have been confirmed by operation, autopsy or pneumography.

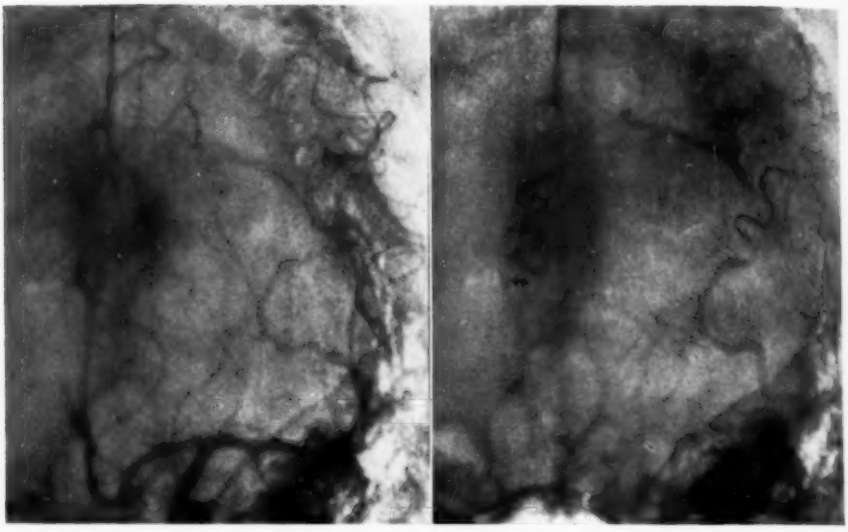


Fig. 10. Case 2. Glioblastoma in the basal ganglia on the left side. The expanding process is localised in the sagittal plane by the internal cerebral (↑) and striothalamic veins (↑), which are displaced more to the right than the anterior cerebral and pericallosal arteries. In the a-p view the striothalamic vein is partly superimposed on the internal cerebral vein. A number of pathologic vessels are drained by the deep vessels.

Tumours in, or infiltrating, the basal ganglia

Case 1 (Fig. 9) is a malignant glioma in the basal ganglia on the right side.

On carotid angiography of the right side, the anterior cerebral and pericallosal arteries are situated in the midline and their curve is slightly more marked than usual. The Sylvian vessels are not altered. From the appearance of the arteries it is clear that a hydrocephalus is present, but the arteriogram does not give information as to whether it is caused by a central expanding process or by something else. On the phlebogram, a displacement of the internal cerebral vein to the left is seen and the posterior part of the basal vein is stretched and depressed. A central expanding process is thus present and may be localised in an area bounded by the internal cerebral, the striothalamic and the basal veins, *i. e.* in the basal ganglia.

Case 2 (Fig. 10) is a glioblastoma in the basal ganglia on the left side.

The anterior cerebral and pericallosal arteries on the left side describe a deeper curve than usual. They are displaced towards the right. The internal cerebral and striothalamic veins are, however, displaced still more towards the right, especially the latter which forms a curve convex to the right and appears partly superimposed on the internal cerebral vein. In this case, in addition to the vascular displacement there is a number of pathologic vessels which are drained by the deep vessels.

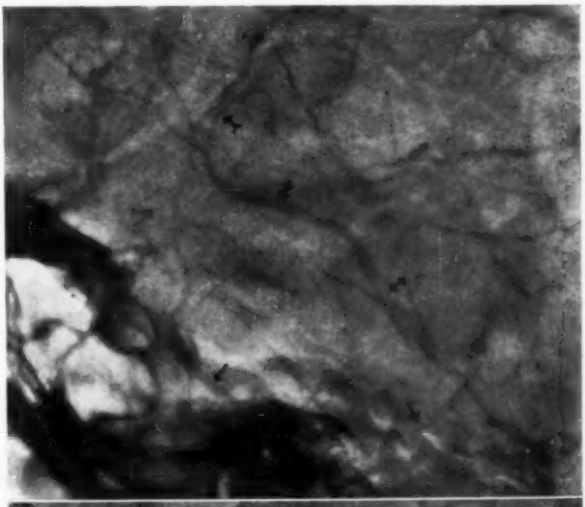


Fig. 11

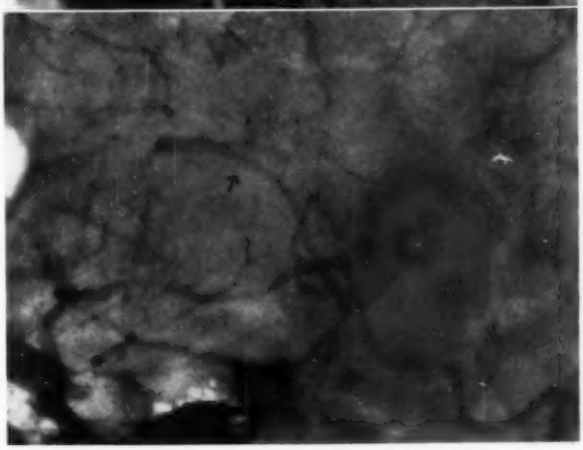


Fig. 12

Fig. 11. Case 3. Glioblastoma in the basal ganglia infiltrating the right hemisphere. The internal cerebral vein (↕) is somewhat depressed. The curves of its contributaries are shallower, especially that of the striothalamic vein (↕) which is elevated. The basal vein (↑) is straightened and depressed.

Fig. 12. Case 4. Tumour situated in the midline. The internal cerebral vein is displaced upwards. On account of this, the striothalamic and internal cerebral veins form a backward diverging angle. It is impossible to localise the tumour in the arteriogram; only hydrocephalus is shown.

Case 3 (Fig. 11) is a glioblastoma originating from the basal ganglia and infiltrating the right hemisphere.

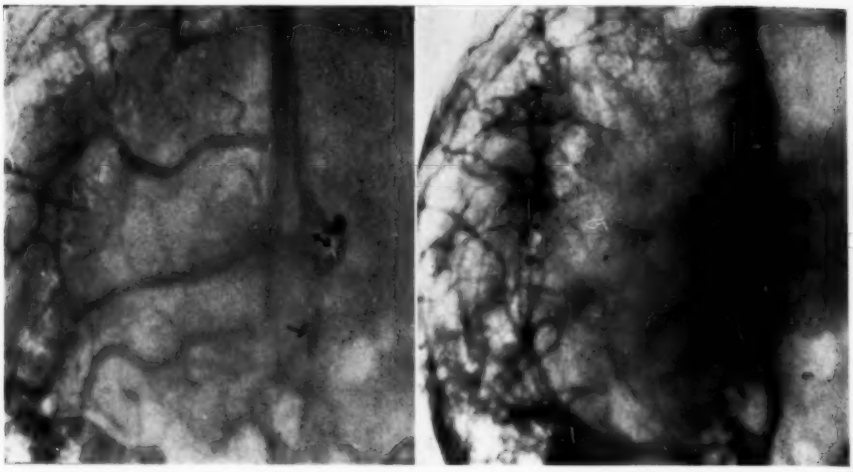


Fig. 13. Case 5. Glioma in the right temporal lobe with characteristic displacement in the arteriogram. The basal vein shows a similar depression as in cases of tumour of the basal ganglia. Although here it is also dislocated medially (↑). Note the difference in displacement of the anterior cerebral artery and the internal cerebral vein (↕) in the a-p views.

Another type of displacement is shown in this case. The curves of the veins coming from the walls of the lateral ventricles are shallower, especially those of the striothalamic vein which is seen to be elevated. Unlike the previous case, the internal cerebral vein is depressed and has lost its smoothly curved contour. The basal vein is straightened and depressed. The pericallosal artery runs in the midline, while the internal cerebral vein and its branches are displaced to the left.

Case 4 (Fig. 12). The anterior cerebral and pericallosal arteries are slightly displaced to the right, but are not otherwise markedly altered. The internal cerebral vein, however, is not shifted laterally, but is displaced upwards in front of the pineal body, forming a convex curve. On account of this displacement, the normal curve, formed by the striothalamic and the internal cerebral veins, is lost in the lateral view and instead, the vessels form a backward diverging angle. The basal vein is slightly straightened and displaced inferiorily. Encephalography in this case showed a tumour in the midline, situated between the cisternae above the entrance of the sella and the third ventricle. The tumour is slightly larger on the left side.

Case 5 (Fig. 13) is a glioma in the right temporal lobe. The basal vein shows a similar depression as in the foregoing cases but the vessel is also displaced medially.

Tumours originating from the basal ganglia straighten and depress the basal vein, but do not displace it laterally. In deeply infiltrating temporal tumours, a similar depression of the basal vein may be seen, but in these cases the vein is also displaced medially.

The position of the basal vein near the medial border of the temporal lobe may be helpful in the diagnosis of the deep infiltration of a temporal tumour. The posterior cerebral artery may not always be filled with contrast medium from the internal carotid artery. However, with our technique, the basal vein, filled with contrast, can practically always be seen. The course of the basal vein and posterior cerebral artery is partly the same and they run together at the medial border of the temporal lobe. If the posterior cerebral artery is not filled, the basal vein, alternatively, may give valuable information.

Tumours in the corpus callosum

Case 6 (Fig. 14) is a malignant glioma in the septum pellucidum and anterior part of the corpus callosum.

The left anterior cerebral and the pericallosal arteries are displaced to the right. The internal cerebral vein is also displaced to the right. Some of the branches from the anterior part of the pericallosal artery are straightened throughout a length of five to six cm. The striothalamic vein is depressed and straightened, forming a slight curve, convex backwards, and making an acute angle with the internal cerebral vein. The anterior part of this vein and the posterior part of the vein of the septum pellucidum form an even curve, convex downwards. There is also a collection of pathologic vessels in front of these veins.

Case 7 (Fig. 15) shows another type of displacement of the deep veins. The pericallosal and marginal callosal arteries are straightened just behind the "knee". There is an area of pathologic vessels which run through a large vein into the striothalamic vein. The latter is forced backwards together with the internal cerebral vein in a concertina-like fashion. There is no lateral displacement of the veins. In this case the tumour is also profusely vascularised. It was found to be a glioblastoma, slightly larger on the left than on the right side.

A tumour situated in the posterior part of the corpus callosum causes a displacement of the middle and posterior part of the internal cerebral vein which is straightened and displaced basally.

Case 8 (Fig. 16). In this case a tumour, the size of a walnut, lies in the posterior part of the corpus callosum. Calcifications of the type generally found in oligodendroglioma, making the tumour easy to diagnose and localise. The phlebogram is, nevertheless, of interest because it shows the boundaries of the tumour inferiorily and posteriorily. The internal cerebral vein has lost its normal curved course. It is straightened and displaced basally.

Case 9 (Fig. 17). The anterior cerebral and pericallosal arteries run in a curve to the right, the anterior part of the pericallosal being slightly displaced basally. The tumour may be more accurately localised from the displacement of the veins. The vein of the septum pellucidum is depressed in a curve, while those from the middle part of the lateral ventricle are depressed and straightened. The distance between the internal cerebral vein and the inferior longitudinal sinus is increased. There is no lateral displacement of the internal cerebral vein. In this case the whole of the corpus callosum is occupied by a tumour which also grows up between the hemispheres.

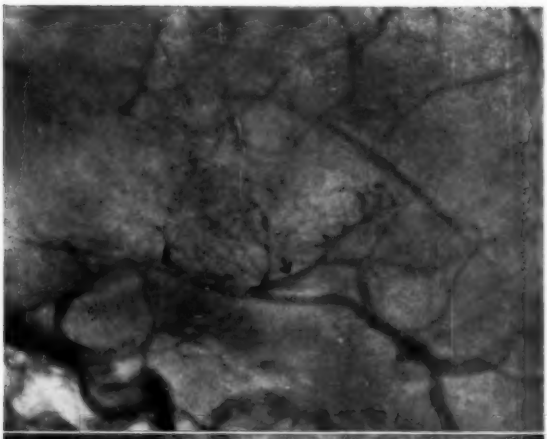


Fig. 14

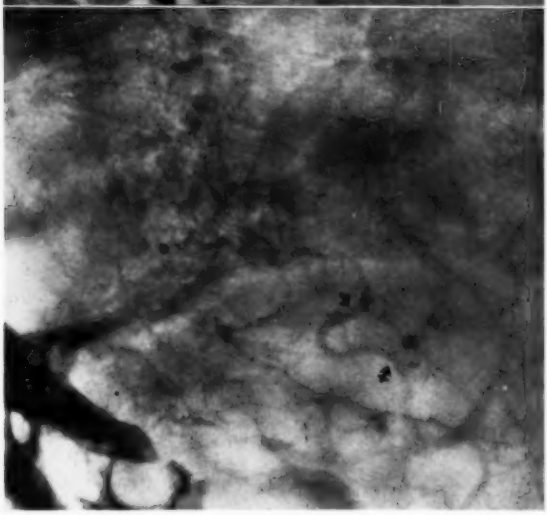


Fig. 15

Fig. 14. Case 6. Displacement of the central veins caused by a tumour in the anterior part of the corpus callosum and the septum pellucidum. The striothalamic vein is depressed, forming a slight curve convex backwards and making an acute angle with the internal cerebral vein. The anterior part of this vein and the posterior part of the vein of the septum pellucidum form an even curve convex, downwards. (In the arteriogram only some branches from the pericallosal artery are straightened and localisation is not possible.)

Fig. 15. Case 7. Glioblastoma in the anterior part of the corpus callosum. Pathologic vessels run through a large vein into the striothalamic vein, which together with the internal cerebral vein (‡) is forced backwards and presents a concertina-like appearance.

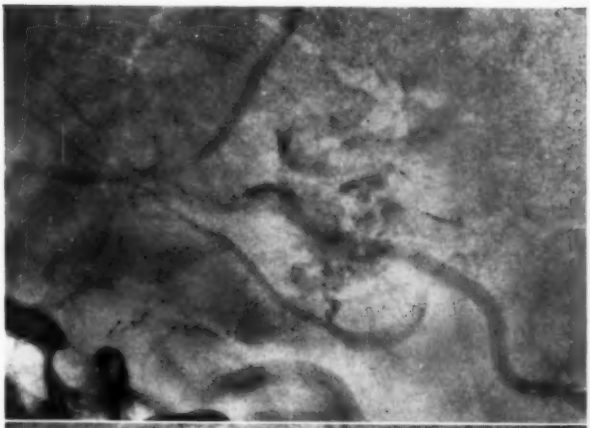


Fig. 16

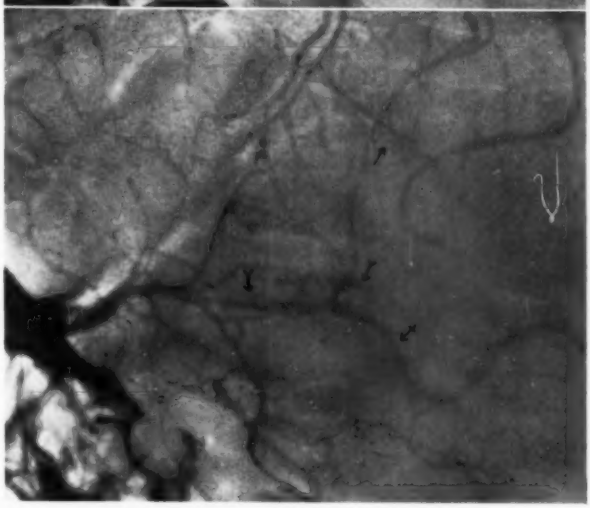


Fig. 17

Fig. 16. Case 8. Calcified tumour in the posterior part of the corpus callosum. The internal cerebral vein has lost its normal curved course. It is straightened and displaced basally.

Fig. 17. Case 9. The whole of corpus callosum is occupied by a tumour depressing and straightening the vein of the septum pellucidum (↑) and the veins from the middle part of the lateral ventricle (↑). The distance between the internal cerebral vein (↑) and the inf. long. sinus (↑) is increased.

It is evident from these cases that tumours in the anterior and the posterior part of the corpus callosum cause different types of venous displacement.

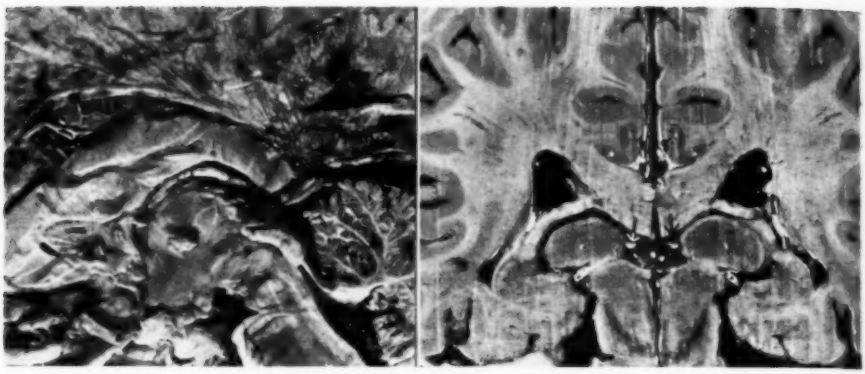


Fig. 18. Autopsy specimen. The internal cerebral veins lie a few mm apart, just above the pineal body and under the splenium.

If the tumour is situated in the anterior part of the corpus callosum it causes a characteristic displacement of the anterior parts of the internal cerebral vein and its contributors, *i. e.* compression from the front, depression and flattening out of the normal curve between the internal cerebral and striothalamic veins.

Tumours in the region of the pineal body

In a normal phlebogram the internal cerebral vein is situated just above the pineal body. In the sagittal and frontal sections of the same anatomic specimen, shown in Fig. 18, the internal cerebral veins lie a few mm apart, just above the pineal body and under the splenium. The intimate relationship between the pineal body and the internal cerebral vein makes it easy to understand that a pineal tumour influences the position of the vein.

Case 10. In this case there is a calcification corresponding to the site of the pineal body, and 1 cm to the right of the midline. On carotid angiography the arteries show a moderate hydrocephalus. The form of the internal cerebral vein is changed by a straightening of its posterior part, which is situated almost 1 cm above the calcification. The vein runs in the midline, about 1 cm from the laterally displaced calcification. A local expanding process is indicated in this case by the change in form of the internal cerebral vein and the increased distance between the vein and the calcification of the pineal body. It was a teratoma, the size of a ping-pong ball.

Case 11 (Fig. 19) is one of a small pineal tumour. The calcified pineal body is not obviously displaced in this case. In the arteriograms the upper part of the carotid siphon is extended upwards. There is no other displacement of the arteries. No changes are seen in the lateral phlebogram. In the a-p view however, the internal cerebral vein is pushed away from the midline and forms a curve, convex laterally.

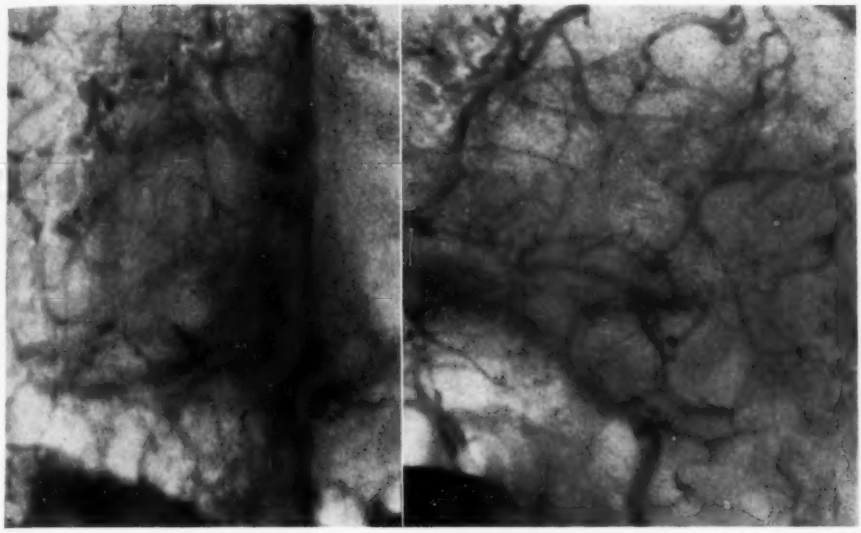


Fig. 19. Case 11. Small pineal tumour. The internal cerebral vein (↑) is pushed away laterally from the midline. No changes are seen in the lateral phlebogram.

Pineal tumours straighten the posterior part of the internal cerebral vein. The distance between the vein and the pineal calcification may be increased and the vein displaced laterally.

SUMMARY

The normal anatomy and variations of the deep cerebral veins and sinuses selectively contrast-filled and examined roentgenologically in a material of thirty cadavers is described. The findings on roentgen examination were checked by dissection and the results from these investigations compared with two hundred normal angiographies. The central veins may be identified so accurately in films obtained in various projections that it is possible to decide whether they are displaced or not. Examples of displacements of the central veins in different situations of central and deeply infiltrating tumours are given.

ZUSAMMENFASSUNG

Die normale Anatomie und die Variationen der tiefen Hirnvenen und Sinus, die in einem Material von 30 Leichen selektiv kontrastgefüllt und röntgenologisch untersucht worden sind, werden beschrieben. Die Befunde der Röntgenuntersuchungen wurden durch die Sektion kontrolliert; die Resultate dieser Untersuchungen wurden dann mit 200 normalen Angiographien verglichen. Die zentralen Venen können auf Röntgenbildern, die in verschiedenen Projektionen hergestellt sind, so genau identifiziert werden, dass

die Entscheidung, ob eine Dislokation vorliegt oder nicht, möglich ist. Beispiele für Verlagerungen der zentralen Venen bei verschiedenen Lokalisationen zentraler und tiefliegender Tumoren werden gegeben.

RÉSUMÉ

L'auteur décrit l'anatomie normale et les variations des veines cérébrales profondes et des sinus opacifiés de façon sélective et examinés radiologiquement sur une série de trente cadavres. Les résultats des examens radiologiques ont été contrôlés par dissection et les résultats de ces recherches ont été comparés avec deux cents angiographies normales. Les veines centrales peuvent être identifiées sur les films obtenus sous diverses incidences avec une exactitude telle qu'il est possible de dire si elles sont ou non déplacées. L'auteur donne des exemples de déplacements des veines centrales pour différents sièges de tumeurs centrales ou infiltrant en profondeur.

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FROM THE ROENTGEN DIAGNOSTIC DEPARTMENT (DIRECTOR: PROFESSOR OLLE OLSSON)
OF THE UNIVERSITY CLINICS OF LUND, SWEDEN

CAROTID ANGIOGRAPHY IN THE DIAGNOSIS OF SPONTANEOUS INTRACEREBRAL HAEMORRHAGE

by

F. Olov Löfgren

The surgical treatment of spontaneous intracerebral haemorrhage is as old as modern neurosurgery. CUSHING reported two cases in 1903. Since that time comparatively few such cases have been operated upon, and then usually a rather long time after the event. The surgical aspects have recently received more attention and neurosurgeons now operate in the acute stage. It has been found that the removal of a haematoma may often save the life of a patient and also accelerate recovery.

The response of these cases to surgical intervention is dependent upon their selection. The most suitable case is one in which the haematoma is situated in the subcortical white matter. Those instances in which the clot lies deep in the basal ganglia region are not amenable to surgical intervention. Precise localization of the lesion is therefore of obvious importance. It is often difficult, and at times impossible, to place the lesion with any precision by clinical means alone. Radiologic investigations, in many instances, may define its position.

There are two radiologic methods available for this purpose, pneumography and angiography. The latter is the method of choice; by its employment, it is possible to localize the lesion, visualize the circulation and define any vascular anomalies. The patients are often very ill and angiography is the less traumatic of the two procedures. We use the method of percutaneous carotid angiography. If an accessible intracerebral haematoma is demonstrated a bore hole is made and a small quantity of the contents aspirated. Oxygen is then introduced into the cavity. Roentgenograms of the skull are obtained and the cavity is localized before removal of the haematoma is attempted.

It appears to be an advantage to remove the haematoma as soon as possible. The patient is therefore investigated in the acute stage, often

on the same day as the haemorrhage occurs. In some instances the patients were first cared for at other hospitals before being referred to us. It was thus not always possible to get cases as early as might be desired. For example, one was not examined angiographically until about 6 weeks after the event.

In the period 1947—1951, 62 cases of intracerebral haemorrhage were investigated by carotid angiography. 33 were examined within 5 days of the bleeding and 54 within 6 weeks. This material consists of these 54 cases, and has been divided into 5 groups.

Group I comprises cases in which the angiograms show an expansive process in the subcortical white matter, *i. e.* not encroaching upon the central structures. In these cases, the haematoma displaces the middle cerebral artery superiorly or inferiorly, and pushes the anterior cerebral artery to the opposite side. The haematoma can usually be localized with some accuracy. These cases are accessible to surgery.

Group II consists of those cases with signs of an expansive process in the deeper structures. The angiogram shows a lateral shift or arching of the anterior cerebral artery. There is sometimes a lateral displacement of the middle cerebral artery. The haemorrhage is usually confined to the basal ganglia and the internal capsule where the nerve tracts are confined to a small area. Lesions in this region cause irreparable damage and are inoperable.

Group III consists of cases in which the vascular pattern is normal. As a rule there is a small haemorrhage or a small area of cerebral softening. But in a few cases there is a large haematoma in the basal ganglia which has ruptured into the ventricular system. Neither of these types lends itself to surgery.

Group IV embraces cases with thrombosis of an artery and cannot be treated surgically.

Group V consists of aneurysms, which are accessible to surgical treatment.

A few cases will be reported as examples of the different groups.

The first 3 cases belong to Group I, *i. e.* haematoma in the subcortical white matter.

Case 1. A 53-year-old man with hypertension was found unconscious in bed. On admission the same day he had a left hemiplegia. Carotid angiography of the right side, done in the acute stage, showed a pronounced displacement of the anterior cerebral artery to the left (Fig. 1a). The middle cerebral artery was pushed markedly upwards (Fig. 1b). These findings indicated an expansive process in the right temporal region. The haematoma was punctured, fluid aspirated, and oxygen and tantalum powder were injected. The roentgenogram showed the haematoma to be in the temporal lobe. It ex-

Fig. 1 a. 1 b.

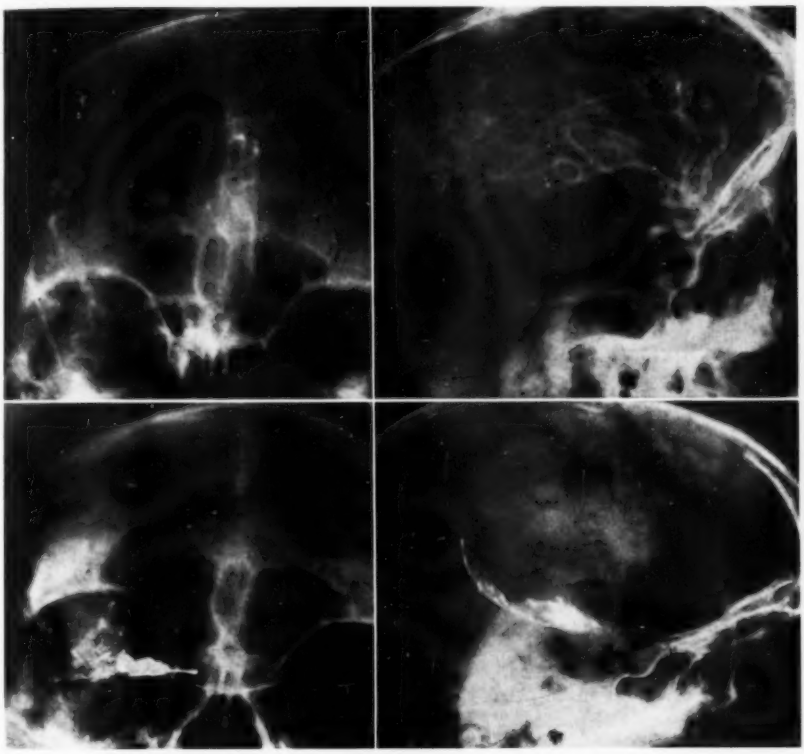


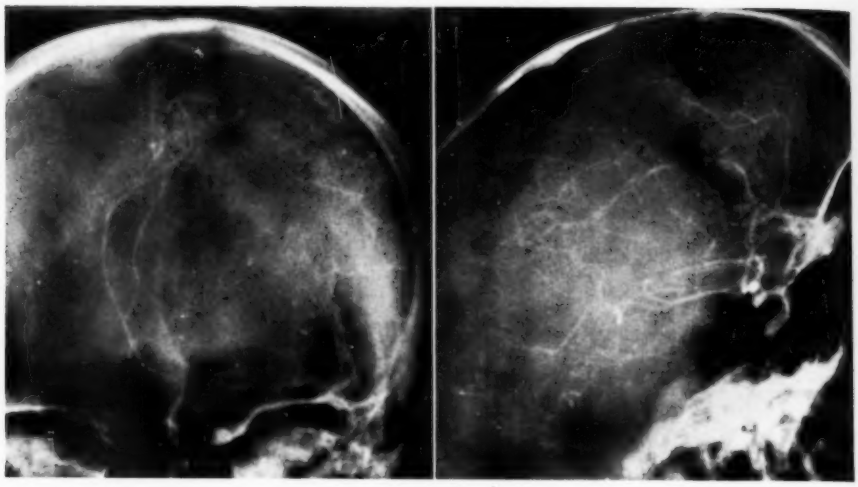
Fig. 2 a. 2 b.

Fig. 1. Pronounced displacement of the anterior cerebral artery to the left. The middle cerebral artery is displaced markedly upwards indicating an expansive process in the temporal region.

Fig. 2. After puncture of the haematoma and injection of oxygen and tantalum powder. The haematoma is situated in the temporal lobe extending anteriorly into the frontal lobe where it continues towards the mid line.

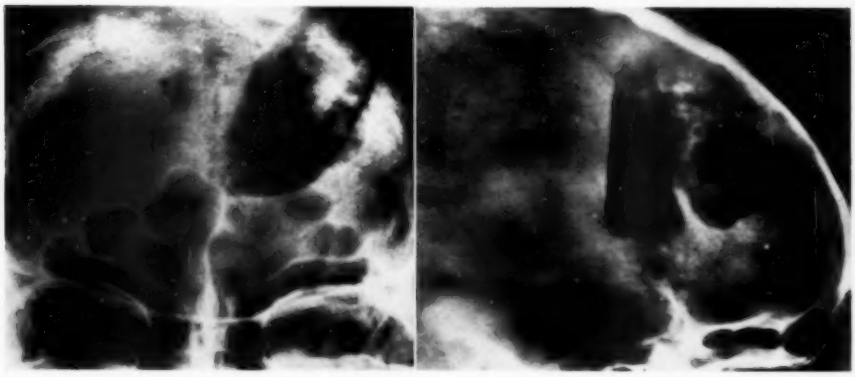
tended anteriorly into the frontal lobe where it continued towards the mid line (Fig. 2a, b). It was removed. Immediately following operation, the symptoms of raised intracranial pressure began to subside. Three months later, the patient was able to walk with the aid of a stick although the paralysis of the left arm persisted.

Case 2. A 36-year-old man with normal blood pressure. Following a bout of alcoholic intoxication, headache of increasing intensity, dizziness and paralysis of the right arm developed. Angiography on the left side, three weeks after the attack, showed the



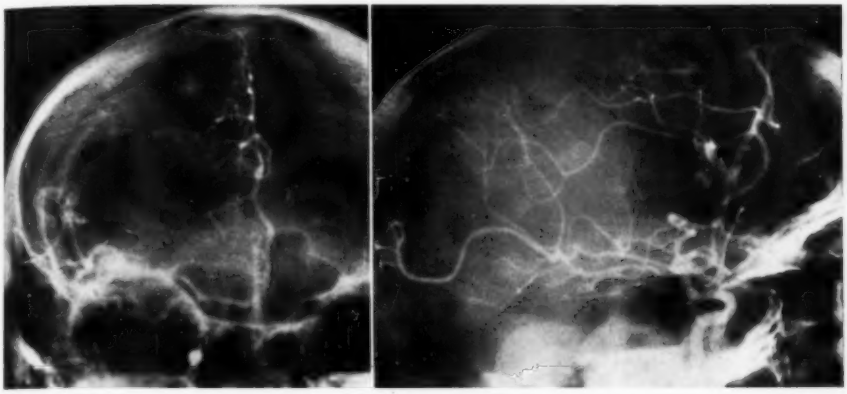
a. b.

Fig. 3. The anterior cerebral artery is displaced in a curve to the right and is also displaced posteriorly. The anterior part of the middle cerebral artery is slightly depressed. These changes indicate a large expansive process in the frontal region.



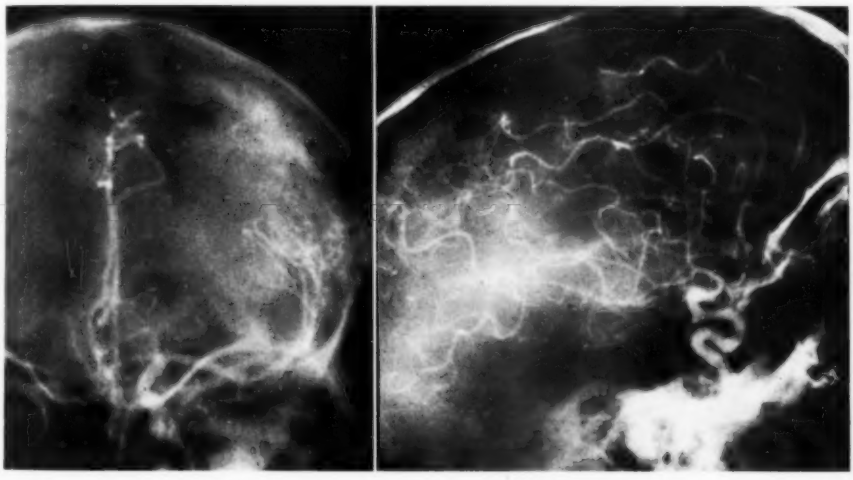
a. b.

Fig. 4. After puncture of the haematoma and injection of oxygen. The large haematoma is situated in the frontal lobe. There is a filling defect in the anterolateral part of the cavity, representing a blood clot.



a. b.

Fig. 5. The anterior cerebral artery is displaced to the left and the anterior part of the middle cerebral artery in the Sylvian fissure is slightly depressed. A cluster of irregular vessels extends from the upper branch of the middle cerebral artery and a large vein from this region passes up towards the sagittal sinus. These findings indicate an arteriovenous aneurysm bleeding into the frontoparietal region.



a. b.

Fig. 6. The frontal view shows a slight displacement of the basal part of the anterior cerebral artery to the right and a lateral displacement of the middle cerebral artery. The lateral view shows no vascular displacement. Diagnosis: a haemorrhage into the basal ganglia.

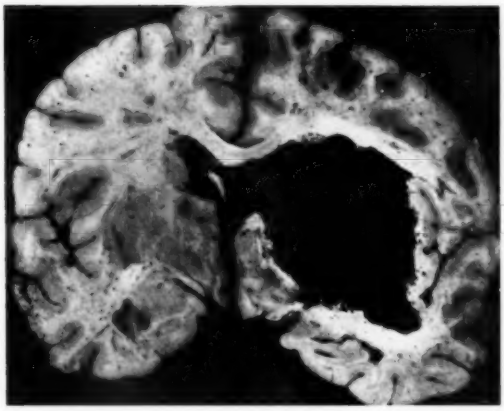
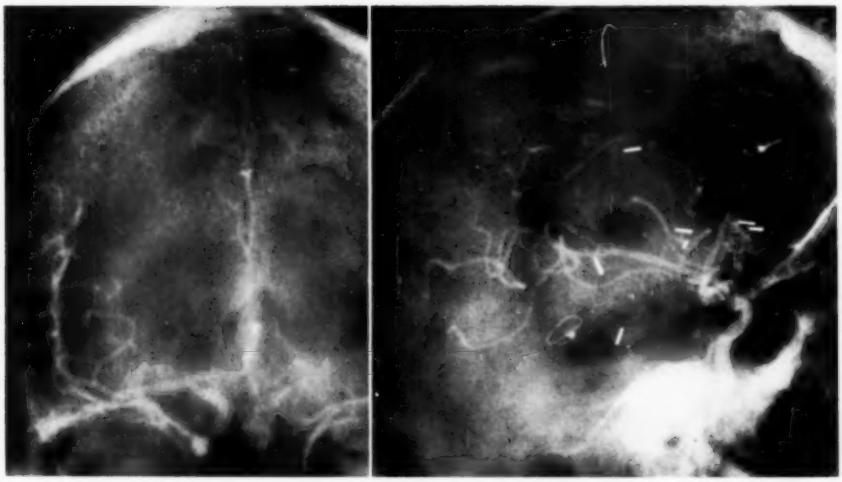


Fig. 7. Post-mortem examination: a large haematoma in the left hemisphere involving the internal capsule and basal ganglia and rupturing into the lateral ventricle.



a. b.

Fig. 8. Clinical signs and symptoms of a haemorrhage on the right side. Angiography of the right side shows no vascular displacement. On the left side drill holes and clips after an earlier operation are seen.

anterior cerebral artery to be displaced in a curve to the right as well as posteriorly (Fig. 3a). The anterior part of the middle cerebral artery was slightly depressed (Fig. 3b). The angiography thus suggested a large expansive process in the frontal region. After puncture and injection of oxygen, a large cavity with a blood clot in its anterolateral part was demonstrated (Figs. 4a, b). Following operation, there was marked improvement in the symptoms. Three months later the patient felt well and returned to his usual work.

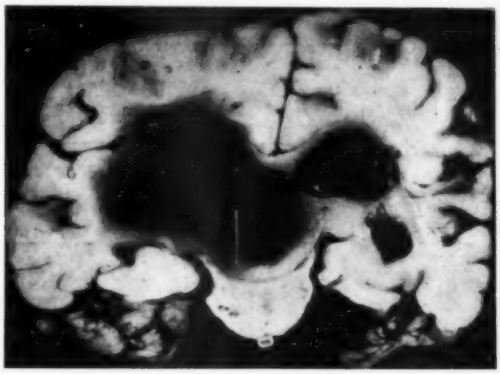


Fig. 9. Post-mortem examination: a large haemorrhage in the right hemisphere involving the internal capsule, striatum, and thalamus, encroaching on the left side and rupturing into the ventricular system.

Case 3. A 39-year-old woman with normal blood pressure had a sudden onset of headache and left hemiplegia. It was possible in this case to demonstrate the source of the bleeding. Angiography of the right side, six weeks after the event, showed displacement of the anterior cerebral artery to the left (Fig. 5a). A cluster of irregular vessels extended from the upper branch of the middle cerebral artery. A large vein from this region passed up towards the sagittal sinus. In addition, the anterior part of the middle cerebral artery was slightly depressed (Fig. 5b). This is an example of an arteriovenous aneurysm bleeding into the frontoparietal region. The haematoma was removed and the aneurysm excised.

The following case belonging to Group II illustrates an expansive process in the deep region of the brain.

Case 4. A 52-year-old woman with hypertension had a sudden onset of right-sided hemiplegia and loss of consciousness. Carotid angiography of the left side, performed in the acute stage, showed a slight displacement of the basal part of the anterior cerebral artery to the right and a lateral displacement of the middle cerebral artery (Fig. 6a). The lateral view showed no vascular displacement (Fig. 6b). The condition was diagnosed as one of haemorrhage into the internal capsule and basal ganglia. The patient died the following day. Post-mortem examination revealed a large haematoma in the left hemisphere involving the internal capsule and basal ganglia and rupturing into the lateral ventricle (Fig. 7).

As an example of Group III one of the few cases, which in spite of a great haemorrhage in the basal ganglia showed no vascular displacement, is reported.

Case 5. A 57-year-old woman had been operated on $2^1/_2$ years previously for a haematoma in the left temporal lobe. She now had a hemiplegia which came on suddenly with loss of consciousness. Carotid angiography of the right side showed no displacement of the vessels (Figs. 8a, b). The patient died 3 days later. Post-mortem examination revealed a large haemorrhage involving the internal capsule and striatum and rupturing into the ventricular system (Fig. 9).

	I	II	III	IV	V	
	Expansive process in subcortical white matter	Expansive process in deep structures	No vascular displacement	Thrombosis	Aneurysm but no expansive process	Angiography failed
54 cases	12	7	22	11	2	2
Operation ...	10	2			2	
Post-mortem		7	3	4		

In this series of 54 cases, angiography demonstrated an expansive process in the subcortical white matter in 12. Ten of these 12 cases were submitted to operation with good results. In the other 2 cases the haematoma was located in the lateral part of the frontal lobe and the patients were not operated as the signs and symptoms gradually subsided. In 7 cases angiography showed lesions in the central structures of the brain. Two of the 7 patients were operated upon. All seven died. This seems to indicate that cases of this type are not amenable to surgical intervention. In 22 cases no vascular displacement was seen. Three of these patients died and were examined post mortem. In one, a number of long-standing and also recent small haemorrhages were seen at the base of the brain. In the other 2, haemorrhages involved the basal ganglia and had ruptured into the ventricular system. Eleven showed thrombosis localized to the internal carotid artery or its main branches. In 2 the angiograms demonstrated arteriovenous aneurysms but no signs of an expansive lesion. In both of these cases operation revealed a haematoma in open communication with the ventricular system. In 2 cases puncture of the carotid artery failed because the patients were markedly agitated.

We use Umbradil 35 % as contrast medium. This is tolerated quite well. Patients are however very agitated during angiography in the acute stage. After injection of the contrast medium the patient often moves his head and the films of the venous phase may not be sharp. We often obtain only films showing filling of the arteries. It is therefore seldom possible to see the central veins when the examination is performed in the acute stage. Many of the patients were in very poor condition, but only two showed complications which might possibly be ascribed to the angiographic procedure. One of these, a 42-year-old man, had a thrombus in the internal carotid artery, through which very little contrast medium flowed. He had a paralysis of the left arm. Six to seven hours after angiography there was also a facial paralysis and progression of the hemiplegia. A slow but considerable improvement then took place until he had another attack 10 months later.

The second patient was a 44-year-old man with hemiplegia and drow-

siness. After angiography the drowsiness increased for a period of about 3 hours. Gradual improvement then occurred.

In summarizing, we may say that carotid angiography is a method which may be used with advantage and without undue risk in the routine investigation of cerebral haemorrhage. It can be used in the acute stage. It may reveal an aneurysm and cerebral thrombosis can be differentiated from haemorrhage. It may show if there is an expansive process or not and above all if the clot is located in the subcortical white matter or in the deep region of the brain. These are distinctions that cannot be made clinically and which are of the greatest importance in the choice of treatment, whether surgical or conservative.

SUMMARY

54 cases of spontaneous bleeding were investigated by means of percutaneous carotid angiography. This method of investigation may be employed without great risk in the acute stage. By means of angiography, cases suitable for surgical treatment may be selected; these are cases in which haematomata situated in the subcortical white matter of the brain can be demonstrated.

ZUSAMMENFASSUNG

54 Fälle von spontanen Blutungen sind mit Hilfe der perkutanen Karotisangiographie untersucht worden. Diese Methode darf ohne grösseres Risiko im akuten Stadium benutzt werden. Mit der Angiographie können für chirurgische Behandlung geeignete Fälle ausgewählt werden. Dies sind Fälle in denen ein Haematom in der subkortikalen weissen Substanz des Gehirns nachgewiesen und lokalisiert werden kann.

RÉSUMÉ

54 cas d'hémorragie spontanée ont été examinés par angiographie carotidienne percutanée. Cette méthode d'examen peut être employée sans grand danger au stade aigu. L'angiographie permet de reconnaître les cas justiciables d'un traitement chirurgical; ce sont des cas ou des hématomes dans la substance blanche sous-corticale peuvent être mis en évidence.

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FROM THE NEUROSURGICAL CLINIC (DIRECTOR: PROFESSOR H. KRAYENBÜHL) OF THE UNIVERSITY OF ZÜRICH, SWITZERLAND

PHLEBOGRAPHY IN BRAINSTEM TUMOURS

by

Hs. R. Richter

In spite of the fact that air studies will still to-day give the most valuable information in cases of posterior fossa and brainstem tumours, the central vessels of the brain are very helpful in the diagnosis of these lesions. Cerebral angiography will be employed more frequently now than years ago because its management is greatly facilitated by puncturing the carotid artery. Deeply situated tumours will therefore be observed more frequently in angiograms than in the era when both angiography and ventriculography required surgical intervention.

As WICKBOM pointed out, pathologic vascularisation enables us in a large number of cases to localise the diseased processes. These cases help us by affording criteria with which to interprete angiograms without pathologic vessels.

Radiologic anatomy of the central vessels

With acknowledgements to the anatomists (such as VICQ-D'AZYR) and to the first angiographers (MONIZ and later, RIECHERT, WICKBOM and the French School) we may summarize our views on the radiologic anatomy of the central vessels as follows. We should especially like to point out the topographic relations of the arteries and veins to the ventricular system (Diagram 1).

Beyond the central or midline vessels, we find only one artery, the anterior choroid artery. It runs from the carotid siphon directly occipitally, roughly parallel to the posterior cerebral artery and meets the choroid plexus of the temporal horn. Anastomosing with the branches of the posterior choroid artery from the posterior cerebral or from the basilar artery, it reaches the trigonum and ends in the cella media. Thus these vessels surround the thalamus.

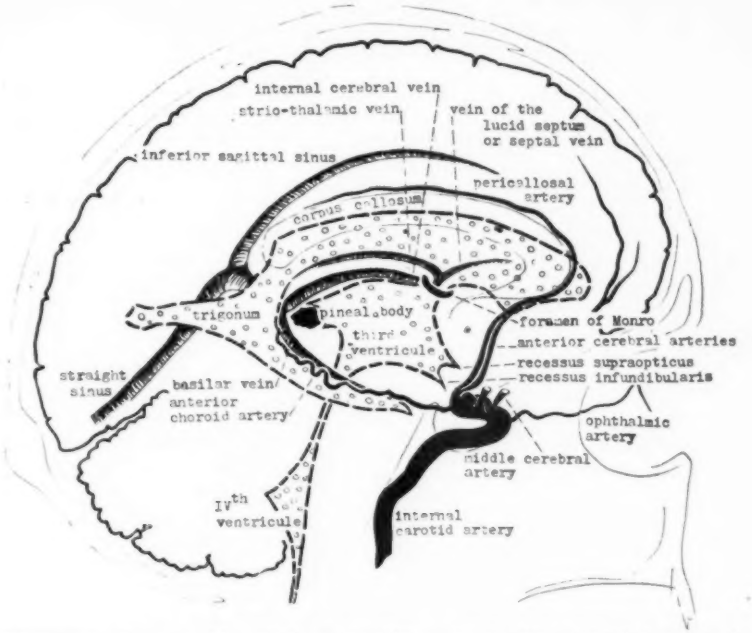

Diagram 1. Topographic relations of midline vessels. The strio-thalamic and the internal cerebral veins form the venous angle of the brain at the foramen of Monro. The anterior choroid artery and the basilar vein constitute the inner vascular axis of the brain.

From the choroid plexus of the temporal horn the basilar vein drains the blood directly into the venous ampulla of Galen, that is into the great cerebral vein.

We found both these vessels very helpful in answering the question whether a tumour lies laterally or medially to the temporal horn. They form an inner vascular axis of the brain. In most deep tumours, this axis is not displaced (in lateral views at least) but we often find an arteriovenous shunt from the anterior choroid artery to the basilar vein or a widened basilar vein alone draining vascularized gliomas (Fig. 1). On the contrary, the axis is displaced to the base or to the midline in tumours of the temporal lobe (Fig. 2).

The value of signs concerning the anterior and posterior choroid arteries is diminished by the fact that these vessels cannot be visualized regularly either by carotid or vertebral angiography alone.

All the remaining vessels to be treated are situated above the basal ganglia and the thalamus. Parallel to the final parts of the choroid ar-

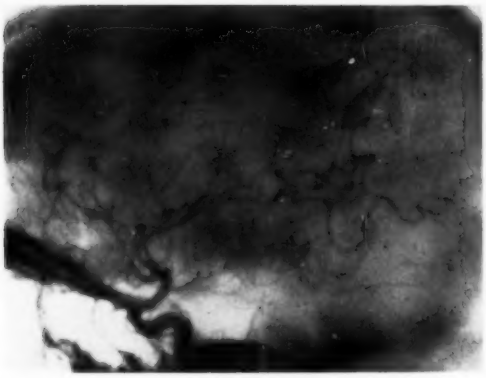

Fig. 1. Malignant astroblastoma in the left basal ganglia and thalamus. No important displacement of the inner vascular axis but arterio-venous shunt from the anterior choroid artery to the basilar vein.

teries runs the terminal or strio-thalamic vein, collecting the blood from the choroid plexus of the trigonum and the upper part of the lateral ventricle. This vessel lies in the telo-diencephalic borderline. Running forwards and upwards, it meets the foramen of Monro and turning suddenly backwards forms, with the internal cerebral vein, a sharp angle (as seen in lateral and axial views) — the venous angle of the brain. In effect, this vessel not only turns backwards, but also slightly medially and runs backwards as the internal cerebral vein in the roof of the third ventricle. It meets the identical vessel from the opposite side, so forming

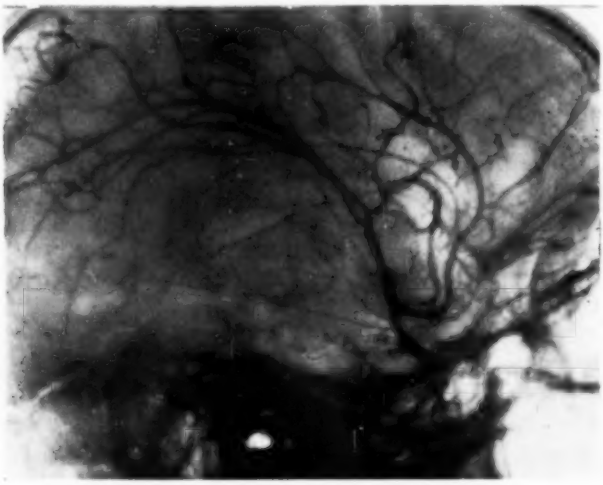

Fig. 2. Astrocytoma of the temporal lobe. Stretching and displacement of the anterior choroid artery to the midline.

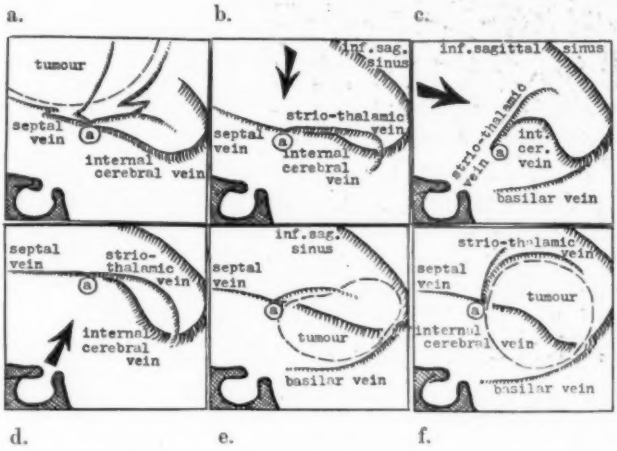

Fig. 3. Displacement syndromes of the venous angle of the brain.

a. Basal displacement with widened central veins in case of a deep precentral glioblastoma.
b. Basal displacement in case of a precentral glioma.
c. Occipital displacement in case of a deep frontal astrocystoma.
d. Lifting in case of a huge craniopharyngeoma invading the third ventricle (suprasellar tumour).
e. Stretching of the internal cerebral vein by pronounced displacement to the opposite side in case of a thalamic glioblastoma.
f. Opening of the venous angle by isolated lifting of the strio-thalamic vein in case of a glioblastoma of the thalamus (see also Diagram 2).

the great vein of Galen which drains into the straight sinus. All these veins lie under the corpus callosum and above the third ventricle and the pineal body.

In contra-distinction to the great cerebral vein which is fixed to the falx and the tentorium, the vessels of the venous angle may easily be displaced. We thus observed the following '*displacement-syndromes of the venous angle*' (Fig. 3).

1. It may be displaced to the base. One observes a flattening of the angle by a parallel lie of the terminal and the internal cerebral veins in the lateral views. These veins may also be widened if they drain a vascularised glioblastoma.

2. Occipital displacement occurs in very large tumours in the deep frontal lobe. A very sharp angle may then be observed in the lateral view; it is caused by the increased sigmoid configuration of the internal cerebral vein.

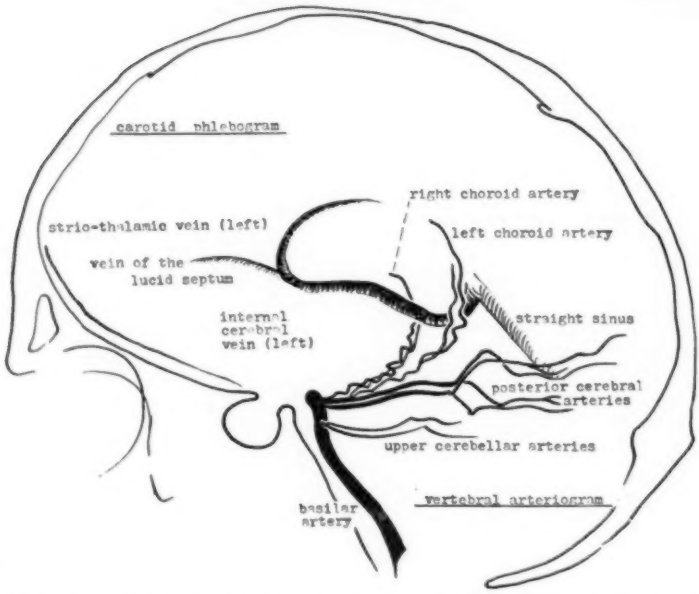

Diagram 2. Diagram of a vertebral arteriogram and carotid phlebogram of a thalamic tumour (glioblastoma). The left choroid artery and the strio-thalamic vein surround the lesion.

3. Lifting of the venous angle is found in large suprasellar tumours invading the third ventricle.

4. Stretching of the veins and a pronounced displacement to the opposite side (noted in the lateral and a—p views) was observed in a case of a thalamic glioblastoma. The sigmoid configuration of the internal vein was clearly diminished. We emphasize the fact that the displacement of the inner cerebral vein away from the midline in the a—p view was much more pronounced than that of one of the anterior cerebral arteries. We consider distention of the vessel to be rather a valuable sign.

5. Finally, an opening of the venous angle may occur by isolated lifting of the strio-thalamic over the internal cerebral vein, as in the following case of a glioblastoma of the thalamus.

A patient, aged 43, had suffered for six weeks with stiffness of the right arm; hemiparesis and a slight psychic alteration then developed and were followed by a severe psycho-organic syndrome with motor aphasia and a spastic hemiparesis on the right side; hemianopia and a positive Babinski were present. Vertebral and carotid angiography

localised the tumour, and on biopsy a glioblastoma was diagnosed. Two months later, the findings were confirmed by the post-mortem examination (Diagram 2).

The vertebral arteriogram shows an important difference in both posterior choroid arteries; the right is normally situated, the left is distended and lifted over the right-sided vessel. The terminal vein running to the wide opened venous angle surrounds, together with the arteries, the space-occupying lesion in the thalamus.

Cerebral angiography may thus localise deep central tumours without pathologic vascularization, as WICKBOM suggested.

SUMMARY

The topographic relations of the central vessels in cerebral angiograms with reference to brainstem tumours are described in detail.

ZUSAMMENFASSUNG

Die Topographie der centralen Gefässe wird in zerebralen Angiogrammen in Beziehung auf Hirnstammtumoren in Einzelheiten beschrieben.

RÉSUMÉ

L'auteur décrit en détail les relations topographiques des vaisseaux centraux en cas de tumeurs du tronc cérébral.

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DISCUSSION

OF THE ANGIOGRAPHIC PAPERS

F. Columella:

In the Neurosurgical Department of the Surgical Clinic of the University of Milano I have, from 1949, carried out vertebral angiography by the percutaneous technique in 123 cases and obtained success in 79 per cent. Owing to lack of space, I shall only discuss the angiograms in the three most interesting of the 96 pathologic cases.

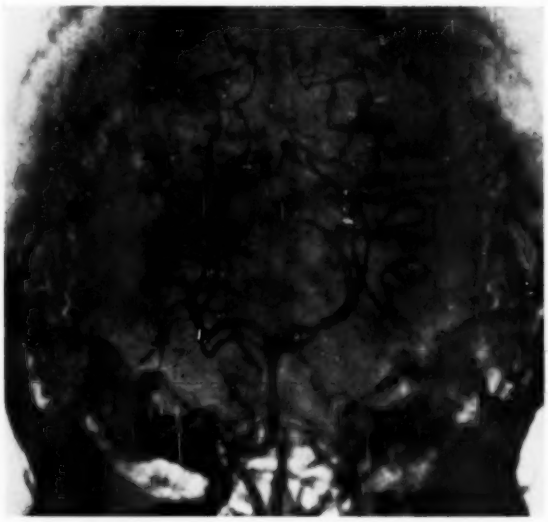


Fig. 1. Left superior cerebellar artery and posterior cerebral artery straightened and displaced medially.

Case 1. Glioma of brain stem, with palsy of the 5th to 12th left cranial nerves and with a contralateral pyramidal syndrome. The left superior cerebellar artery and the

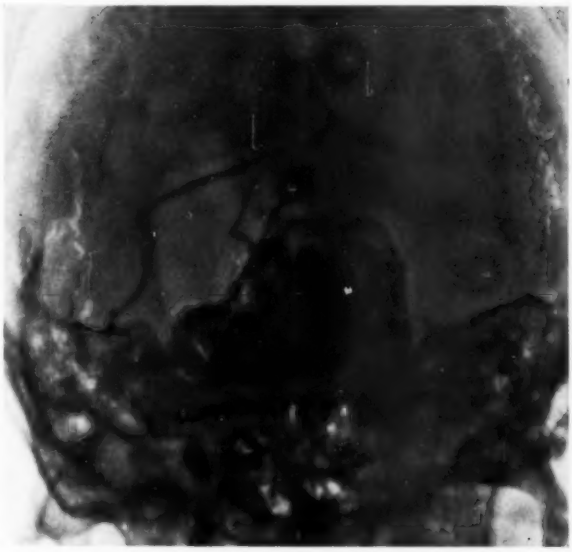


Fig. 2. Vascular malformation.

left posterior cerebral artery were concentrically displaced and straightened. A diagnosis of an expansive process in the left half of the pons and left cerebral peduncle was made (Fig. 1).

Case 2. A woman entered the Clinic with a syndrome of multiple sclerosis. Encephalography disclosed symmetrical hydrocephalus of the lateral ventricles, but failed to visualize the third ventricle. Moreover, on the half-axial posterior encephalogram, a cupola-shaped shadow, typical of a tumour growing up from the floor of the fourth ventricle was seen. The vertebral angiography, however, clearly proved it to be a vascular malformation of a cirsoid type (Fig. 2).

Case 3. A woman slowly developed, over a period of ten years, a complex mesencephalic syndrome, associated with right lateral hemianopsia and signs of intracranial hypertension. Left carotid angiography demonstrated symmetrical hydrocephalus of a marked degree, together with vertical displacement of the posterior communicating artery and vertical displacement and straightening of the posterior cerebral artery. Vertebral angiography showed a vascular malformation. In the lateral arteriogram (Fig. 3) it was possible to recognize a rather large although not sclerotic vertebral artery and, what is more, even during the arterial phase, a very large vein, which emptied into the vein of Galen, near the straight sinus. It was possible to see also a slightly more dilated internal cerebral vein. In the a—p projection (Fig. 4) this pathologically large vein, proved to be the left basal vein. It thus seems that a diagnosis of an arterio-venous fistula between the basilar artery and the basal vein, may be possible.

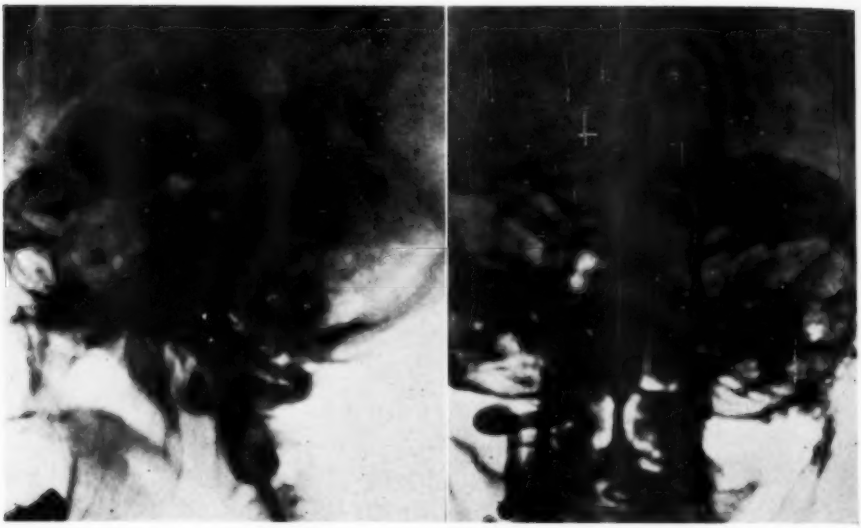


Fig. 3. Fig. 4.

Fig. 3 & 4. Vascular malformation. The dilated left basal vein empties into the vein of Galen.

S. Morson:

Commenting on Dr. JOHANSSON's excellent paper, may I make reference to experimental work, essentially of a neurosurgical nature, carried out twelve years ago in the Department of Surgery, New Medical School, Sydney University, which I think is relevant to the present subject of venography as it completes the picture of Galenic drainage.

At that time the problems under consideration were briefly these, in the first place could an expanding lesion either above or below the cerebellar tent kink and obstruct the great vein of Galen; and secondly if obstructed would the venous congestion so produced in the choroid plexuses increase intracranial pressure by excessive c. s. f. production over a significant period of time. Obviously only the first part of this research project is of interest to members of this symposium.

It had been postulated some time before by STOPFORD in England that the anterior end of the straight sinus, where it is joined by the great vein, might be elevated thus kinking the vein around the splenium of the corpus callosum; this elevation being brought about indirectly by

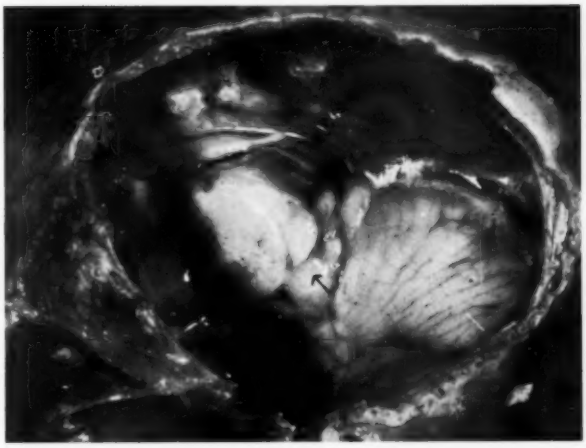


Fig. 1. Galenic axis. Posterior limit fixed by straight sinus, anterior limit moves with soft tissues of brain, obstruction occurring at transverse fissure and not in the loop.

lateral movement of the sail-like falx lifting this point, or directly by pressure beneath the tent. These observations were made in the formalin hardened preparations. In dissections of the fresh brain carried out by us it was seen that the anterior end of the straight sinus was a relatively fixed point but that the internal cerebral and great cerebral veins were the structures which could be displaced and twisted as they lay associated with compressible parts of the brain stem. The whole of this system could thus be likened to a stock whip the handle being represented by the straight sinus and the flexible cord by the great vein, internal cerebral veins and the terminal vein so that, of course, the great vein would not be expected to show as much displacement as the terminal portion.

Observations were also made on the macaque monkey and these experiments were essentially of an acute nature, in that in anaesthetised monkeys intracranial pseudo-tumours were created in a period of five minutes by blowing up a small rubber balloon with thorotrast, the vein of Galen being filled simultaneously with thorotrast in a retrograde manner by means of a cannula inserted into the straight sinus.

The following results were obtained. Expanding pseudo-tumours above the tentorium cause no blockage by kinking of the Galenic axis; lateral shifts not being significant for the experiment. However, expanding lesions below the tentorium, at a stage just before respiration was slowed

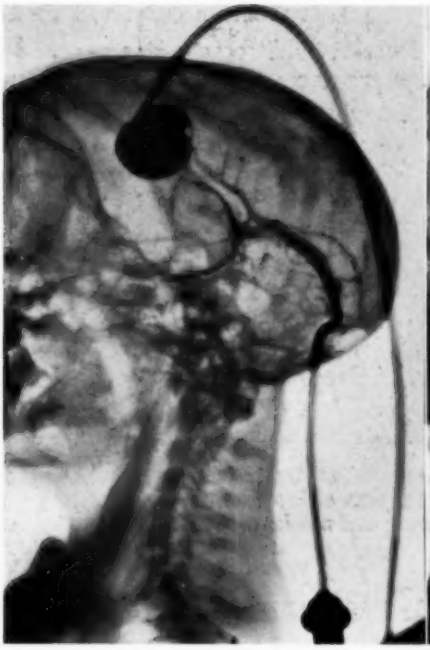


Fig. 2. Retrograde contrast filling of the great vein of Galen. 1 cc. laterally placed supratentorial pseudotumour causing no obstruction.

Fig. 3. Laterally placed supratentorial 2 cc. pseudotumour causing no obstruction.

or halted, caused a blockage at the point where the two small internal cerebral veins joined the great vein.

The reason for this became apparent when the freshly dissected monkey skull and brain were examined, when it was noted that the rapid subtentorial expansion of a pseudo-tumour caused the mid-brain and cerebellum to travel upwards through the incisura. This upward movement strangulated the small veins where they were fixed or bound down by the leptomeninges at the mouth of the transverse fissure below the splenium of the corpus callosum. This mesencephalic piston, or plunger effect, has of course been recognised by many writers and it can occur in either direction.

It was thus my opinion at the time that with slowly-growing lesions, either local or remote, the vein of Galen and its immediate tributaries

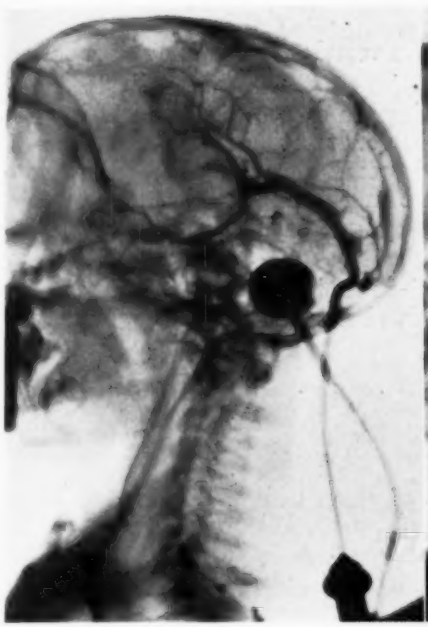


Fig. 4. Infratentorial midline $^1/_2$ cc. pseudo-tumour causing no obstruction.

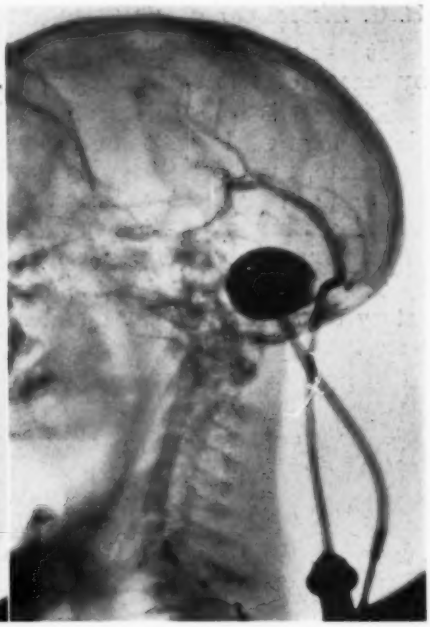


Fig. 5. Infratentorial midline 1 cc. pseudo-tumour causing obstruction at anterior limits of Galenic axis, presumably by upward brainstem displacement.

might take up characteristic configurations and, possibly, show well marked secondary anastomotic channels without any evidence of actual obstruction but that with rapidly occurring lesions in the posterior fossa, such as intra-cerebellar post-traumatic bleeding, Galenic obstruction of the type experimentally produced might possibly occur.

In conclusion then I would like to thank you for the opportunity of referring to this work, which as yet, does not appear to have been studied in full or its practical application considered in the diagnosis of expanding posterior fossa lesions.

B. G. Ziedses des Plantes:

It is sometimes possible to show the vessels of a cervical spinal tumour by means of vertebral angiography.

Figure 1 is an arteriograph obtained in a case of a cervical haemangioma. Figure 2 shows the result when subtraction is performed. In this procedure, the arteriogram is superimposed on a full size diapositive of the preliminary roentgenogram. Certain arteries had been tied during a laminectomy and as the patient's symptoms had deteriorated, vertebral arteriography was performed.

The arteriograph shows the arteries running down from the vertebral artery to the haemangioma and it is obvious that the ventral arteries were not ligated.

Fig. 1. Vertebral arteriogram in a case of cervical haemangioma.

Fig. 2. The result of subtraction.

FROM THE ROENTGEN DEPARTMENT (DIRECTOR: PROFESSOR ERIK LINDGREN), SERAFIMERLASARETTET, STOCKHOLM, SWEDEN

PNEUMOGRAPHIC DIAGNOSIS OF MENINGEOMATA OF THE FALX

by

Ture Andersson

Meningeomata of the falx together with other parasagittal meningeomata are commonly treated from a neuroradiologic point of view, as a homogeneous group presenting the same pneumographic appearances. Such is the case in LYSHOLM's Das Ventrikulogramm. OLIVECRONA and ELSBERG class falx meningeomata, from a clinic standpoint, among the parasagittal group, while CUSHING describes them separately.

Inasmuch as the falx cerebri extends as a sickle-shaped dividing wall deep down between the cerebral hemispheres, meningeomata originating from the falx exhibit more variable pneumographic changes than parasagittal tumours situated lateral to the sinus. The seat of meningeomata arising from the deeper parts of the falx corresponds more closely to that of central tumours, such as glioma of the corpus callosum, than to meningeomata lateral to the sinus.

The falx meningeoma material from Serafimerlasarettet from 1935 to 1951 has been studied with particular reference to this relationship. The pneumographic observations have been collated with the operative findings.

Preoperative pneumography had been performed in the majority of the cases. The few cases in which this examination had not been carried out are not included in this study. All tumours in the material have been verified by operation and subsequent histologic examination. In a few cases autopsy had been performed, but in all, the tumour had been operatively removed previously. Accordingly there were no preparations with the tumour in situ; determination of the seat and size of the tumours and their relations to adjacent structures was therefore based upon the operative findings.

The falx cerebri is a process of dura, descending vertically between the cerebral hemispheres from the crista galli in front and extending

back to the confluens sinuum. Its posterior portion blends with the tentorium cerebelli. The falx is broadest behind and narrows in front; at its base, the dural laminae enclose the superior sagittal sinus, the inferior sagittal sinus running along the free inner margin of the falx.

The relation to the falx of the tumours included in the material studied, 51 cases, varied widely. In 36 cases, the tumours were localized to the falx without involving the superior longitudinal sinus or extending laterally. Sixteen of these tumours were situated on only one side of the falx (Fig. 1 a). Nineteen lay on both sides of the falx, while 14 grew through the falx without reaching its inferior margin (Fig. 1 b) and five

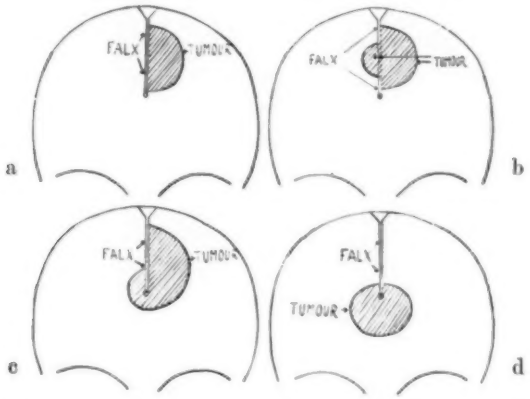


Fig. 1. Diagrams illustrating various modes of tumour growth on the falx. (a) Unilaterally growing tumour. (b) Tumour growing through the falx without reaching the inferior margin. (c) Tumour growing in under the free falx margin and over onto the other side. (d) Tumour originating from the inferior margin of the falx.

under the free margin of the falx and over to the other side (Fig. 1 c). With only one exception, these bilateral tumours were markedly asymmetric, the tumour being considerably larger on one side of the falx than on the other. In one case, the tumour originated from the inferior margin of the falx (Fig. 1 c). In three cases in which the tumours were situated occipitally, these latter extended over on the tentorium cerebelli.

In the remaining fifteen cases, the tumours grew in both the falx and the sinus, or extended laterally.

The communication principally deals with those tumours which grew solely in the falx, including the few which extended over onto the tentorium.

In order to facilitate the description of the pneumographic appearances in the various regions, the tumours have been denoted according to OLIVECRONA's classification as those of the anterior, middle or posterior thirds of the sinus. The general pneumographic appearance presented by the tumours will be reviewed first. The pneumographic changes are illustrated by schematic drawings, made by a collocation of practically all tumours in each region. Certain very large and some relatively symmetrically growing bilateral tumours have not been included.

Corresponding to the anterior third of the sinus, twelve meningeomata involving only the falx were found. The tumours from the anterior narrow region of the falx near the crista galli, all large, and bulging far into the frontal lobe, displaced the ipsilateral anterior horn backwards and towards the contralateral side and produced an even impression in its anterior portion (Fig. 2 a). The anterior part of the third ventricle was displaced backwards and its anterior contour straightened. The superior part inclined from the tumour side. The septum lucidum, which was situated one to two centimeters on the contralateral side of the mid line, stood in a practically vertical arch, concave from the tumour side.

The tumours which originated somewhat farther back on the falx, corresponding to the mid portion of the anterior third of the sinus, presented similar pneumographic appearances. They differed from the foregoing group in that the ipsilateral anterior horn was also displaced basally with an impression inferiorly, directed backwards. In addition, only the basal part of the third ventricle lying nearest the foramen of Munro was displaced backwards, while the anterior part was unaffected (Fig. 2 c).

In the posterior part of the anterior third of the sinus, the tumours exhibited a different pneumographic appearance, corresponding more nearly with that of the tumours in the middle third of the sinus. They will therefore be discussed together. The majority (twenty) of the tumours were situated in the middle third of the sinus, varied greatly in size and were markedly asymmetric. Some were situated high up under the sinus and others deep down at the lower margin of the falx. On the whole the pneumographic appearances presented by these tumours consisted of a basal depression of the ipsilateral lateral ventricle with an even, well-delimited impression in its superior part, and contralateral displacement of the lateral ventricle (Figs 2 c & d). The superior part of the septum lucidum was inclined contralaterally, as was the third ventricle to about the same degree. One condition is especially worthy of note. Corresponding impressions directly under the tumour tilted the roof of the lateral ventricle medially, that is to say, the medial part of the upper contour was lower than the lateral part (Fig. 3). This may be explained by the situation of the falx meningeomata immediately in the mid line. The angle of tilting in the majority of the cases was more

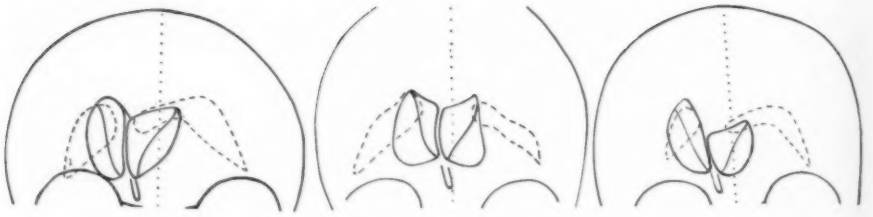


Fig. 2 a_1 2 b_1 2 c_1

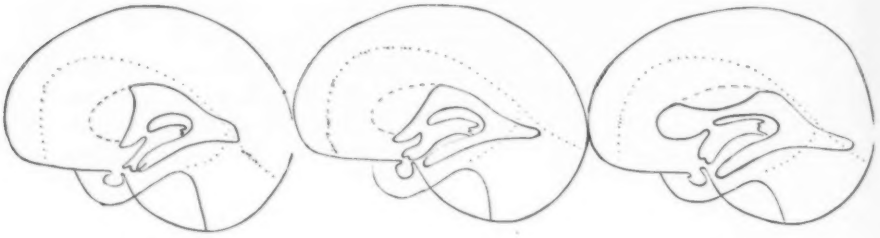


Fig. 2 a_2 2 b_2 2 c_2

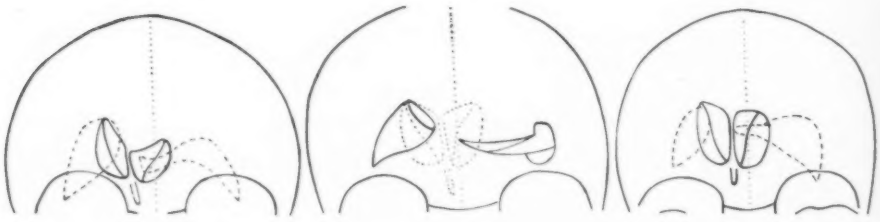


Fig. 2 d_1 2 e_1 2 f_1

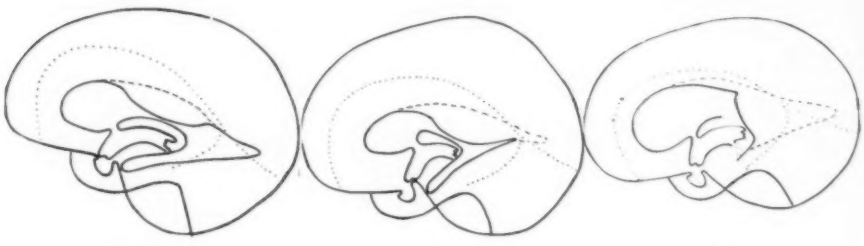


Fig. 2 d_2 2 e_2 2 f_2

Fig. 2. Schematic drawings illustrating the pneumographic appearances presented by falx meningeomata in various regions. (a) Anterior part of the anterior third of the sinus. (b) Middle part of the anterior third of the sinus. (c) Posterior part of the anterior third and anterior part of middle third of the sinus. (d) Middle part of the middle third of the sinus. (e) Posterior part of the middle third of the sinus. (f) Posterior third of the sinus.

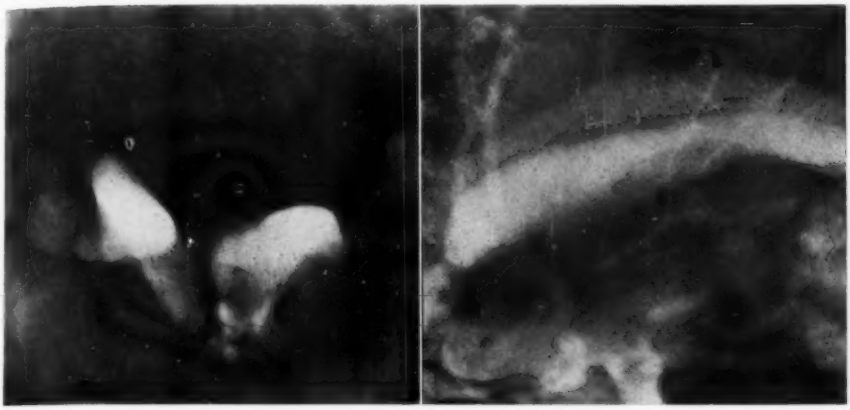


Fig. 3. Left-sided meningeoma growing solely in the falx. The roof of the lateral ventricle under the tumour is lower in its medial than in its lateral part.

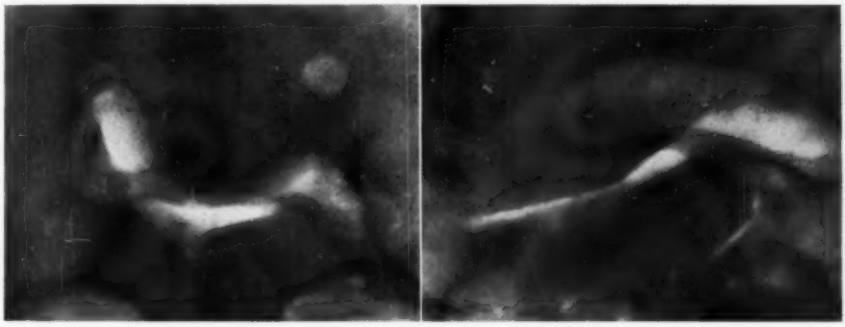


Fig. 4. The roof of the lateral ventricle under a left-sided falx meningeoma is horizontal.

than 10° in relation to the horizontal plane. In some cases however, the tilting was slight. There were only two cases in which the roof of the lateral ventricle under the tumour was tilted outwards (Fig. 4). In both instances the tumours were large and deep-seated. The atypical appearances are explicable if the tumours extended far laterally into the hemispheres. In the reports of the operations on the two cases however, there was unfortunately no definite information on this point.

In an additional two cases, the pneumographic appearances in the middle third of the sinus differed in certain respects from the others (Fig. 2 c). These two tumours were situated in the most posterior part

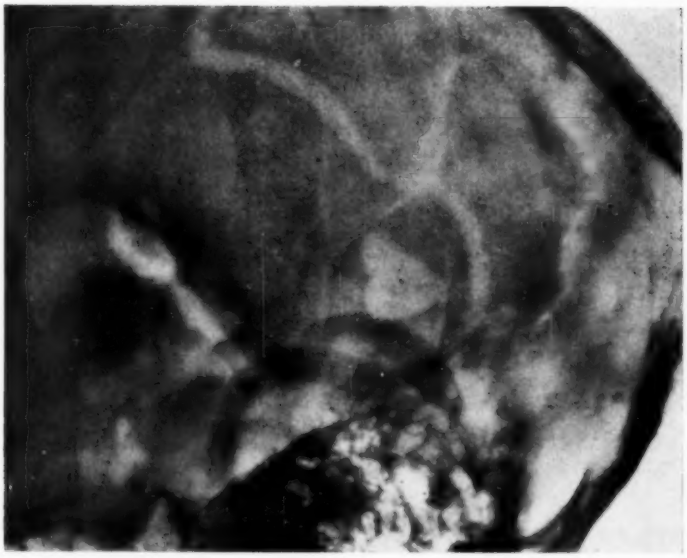


Fig. 5. Falx meningeoma extending over on the tentorium. Tumour tissue was also present on the under surface of the tentorium. Note the kinking of the aqueduct.

of the region. The lateral ventricle on the tumour side was not only displaced contralaterally and depressed, but also displaced forwards.

There were only five tumours corresponding to the posterior third of the sinus. Of these, three extended over onto the tentorium cerebelli. Four were moderate in size, while one was very large and also grew on the under surface of the tentorium. The tumours displaced the posterior horn and the trigone forwards or forwards and basally (Fig. 2). The ventricular system was also displaced contralaterally but to a lesser degree than by tumours situated farther forward. The septum lucidum did not incline, or but slightly, from the tumour side. In one case in which tumour tissue was also present on the under surface of the tentorium, the aqueductus cerebri was displaced forwards and kinked (Fig. 5).

(The examination technique of the temporal horns in this material was not constant throughout the 16 years. The influences of the ventricular system on these regions by falx meningeomata are therefore not discussed. For further details the reader is referred to LINDGREN's monograph.)

A comparison between the pneumographic changes resulting from meningeoma of the falx and from parasagittal meningeoma situated lateral to the sinus showed that certain differences exist. A falx menin-

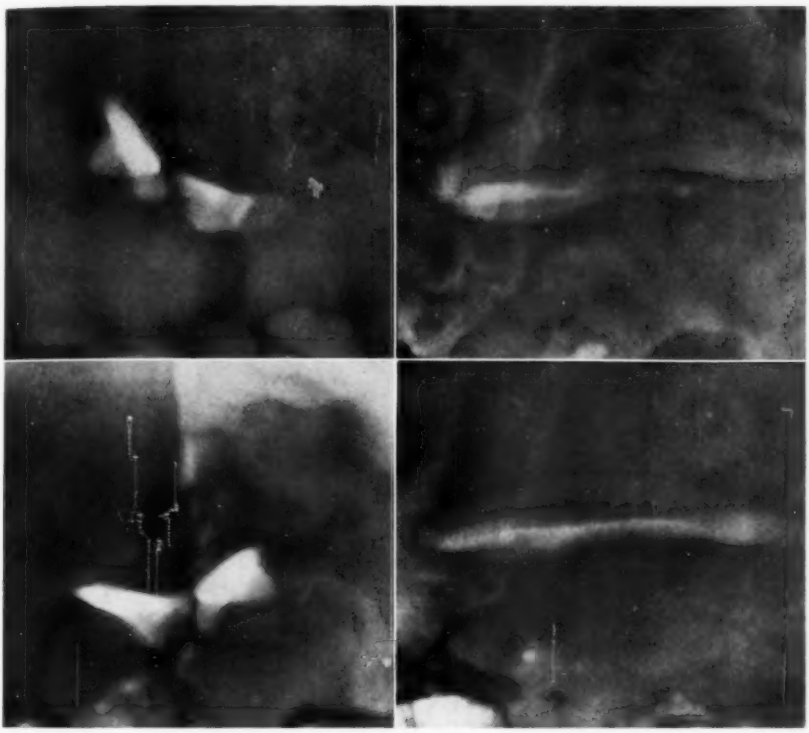


Fig. 6. Unilaterally growing parasagittal meningeomata situated lateral to the sinus. (above) The roof of the lateral ventricle under the tumour is tilted outwards. (below) The roof is horizontal.

geoma, by reason of its deeper situation, frequently caused more marked indentations in the lateral ventricles than a tumour lying lateral to the sinus. Such differences are altogether too variable, however, to be of great differential diagnostic value. In one respect a certain difference, affording greater possibilities of a pneumographic distinction between the two types of tumours, existed — the tilting of the roof of the lateral ventricle proved to vary. As stated earlier, in the cases of falx meningeoma the roof of the lateral ventricle under the tumour was generally tilted medially so that the medial part was lower than the lateral (Fig. 3). This condition is explained by the situation of the falx meningeoma near the mid line. A parasagittal meningeoma, situated lateral to the sinus, should, due to its situation, depress the more lateral parts of the ventricle. This proved to be true in the cases reviewed. Among twenty-eight cases of

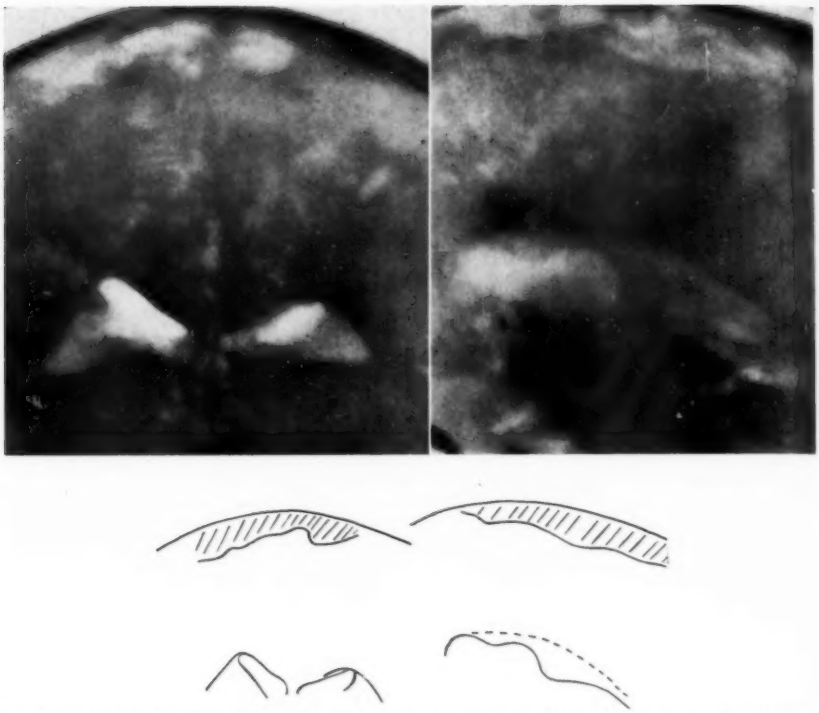


Fig. 7. Right-sided meningeoma growing solely in the falx. Air is present subdurally above the tumour. Sitting position. (below) Diagrams.

parasagittal meningeoma lateral to the sinus, the roof of the lateral ventricle under the tumour was tilted outward in fourteen cases. That is to say, the lateral part was lower than the medial, in contradistinction to that obtaining in cases of falx meningeoma. In ten cases the roof under the tumour lay practically horizontally and, in two cases, with a slight tendency to an inward tilting (Fig. 6). In only one case did the roof tilt definitely inwards under the tumour. In three cases tilting under the tumour could not be determined from the pneumogram. The angle of the roof of the lateral ventricle directly under the tumour cannot always be defined in pneumograms taken in conventional projections. For this purpose the region in question must be examined with a tangential, or almost tangential, beam direction. The tilt of the parts of the lateral ventricle in front of or behind the tumour can be misleading. They are usually depressed under the falx and, as a rule, tilted medially.

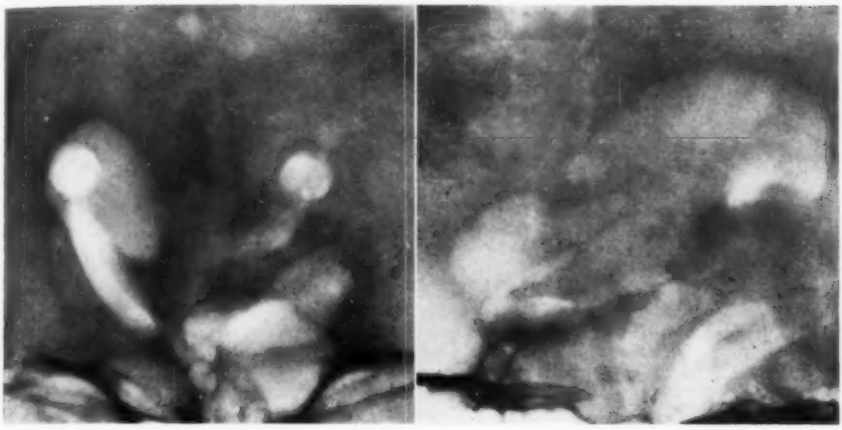
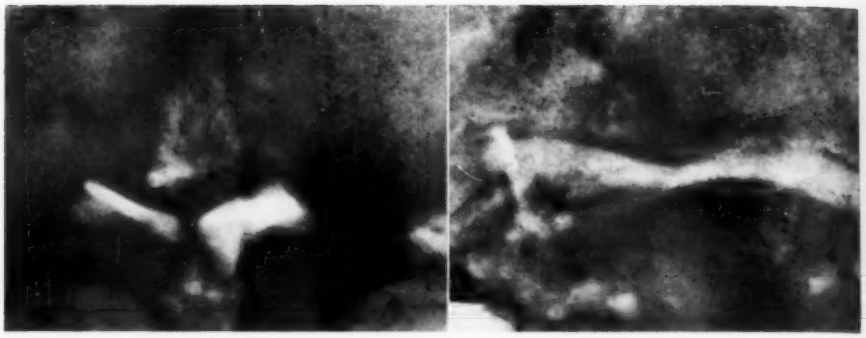


Fig. 8. Meningeoma originating from the lower margin of the falx. Deep even impressions in both lateral ventricles. Pinching off of the left lateral ventricle.

The fifteen tumours growing both in the falx and in the sinus and lateral to the sinus most nearly resembled the parasagittal tumours lateral to the sinus. In practically all cases the roof of the lateral ventricle under the tumour was horizontal. In no case it was tilted medially. It should be pointed out that in the majority of these cases the greater part of the tumour grew lateral to the sinus. However, in few instances the larger part of the tumour grew in the falx.

The differential diagnosis between falx meningeoma and meningeoma lateral to the sinus is facilitated if air is present subdurally. Should it be possible to displace subdural air above the tumour, the tumour cannot be adherent to the dura lateral to the sinus (Fig. 7).

Due to its deep situation, a meningeoma of the falx not infrequently may produce pneumographic appearances similar to those obtained in certain cases of glioma of the corpus callosum. This is particularly true of some types of falx meningeoma. Those which originate from the lower margin of the falx, or grow in under it, frequently produce large impressions in the lateral ventricles and markedly depress them basally, flattening the corpus callosum. They often cause a pinching off of one or both of the lateral ventricles (Fig. 8). The impressions in the lateral ventricles produced by falx meningeomata are, however, even and well delimited. In contradistinction, gliomata of the corpus callosum, by growing into the lateral ventricles, give rise to irregular indentations with broken contours. Moreover, through invading the septum lucidum, the corpus callosum tumours generally force the lateral ventricles apart,



a b

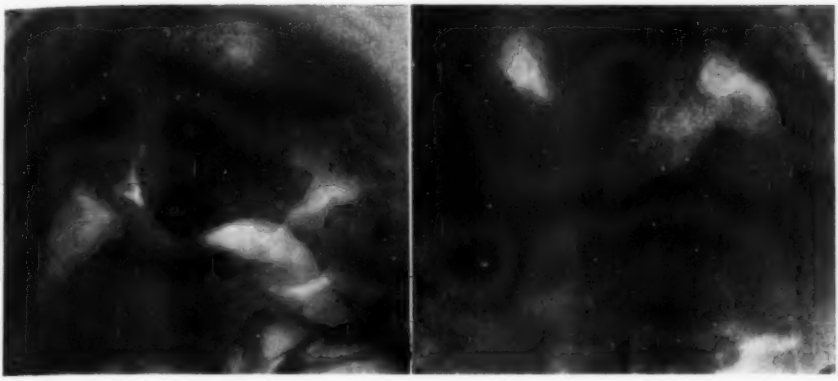
Fig. 9. The cisterna corporis callosi is air-filled under a bilaterally growing falx meningeoma (arrows). Impressions in the upper parts of both lateral ventricles. (a) A. p. projection. (b) Lateral projection. Sitting position.

which never occurs with meningeomata. On the other hand, a deep-seated meningeoma originating from the falx may entirely pinch off a lateral ventricle in the sagittal plane. By less experienced investigators this might be confused with a downward growth into the septum lucidum.

A glioma in the corpus callosum, however, may give less pronounced pneumographic appearances. The irregular growth into the lateral ventricles may be absent, as may the growth downwards into the septum lucidum. The only change may consist of a depression of the lateral ventricles of the same appearance as in a meningeoma of the falx. If such is the case, encephalography, should it be possible to direct air into the cisterna corporis callosi, offers information of greater differential diagnostic value. Figure 9 shows how the air fills out the cistern under a meningeoma growing symmetrically on both sides of the falx. In Figure 10, from a case of a falx meningeoma growing unilaterally, there is also air in the cisterna corporis callosi under the tumour and, in addition, air lies as an envelope around the greater part of its outline.

Such conditions could never arise in the case of tumours growing in the corpus callosum. It is true the air can pass into the cisterna, but the air-filling terminates, in the cases studied, at the posterior or anterior limit of the tumour and, of course, cannot pass under a tumour in the corpus callosum (Fig. 11). It is possible that the cisterna corporis callosi may be air-filled above a small glioma in the corpus callosum. However, this did not occur in any case studied in this investigation.

The air-filling of the cisterna corporis callosi is accordingly of the greatest value in the differential diagnosis between falx meningeomata



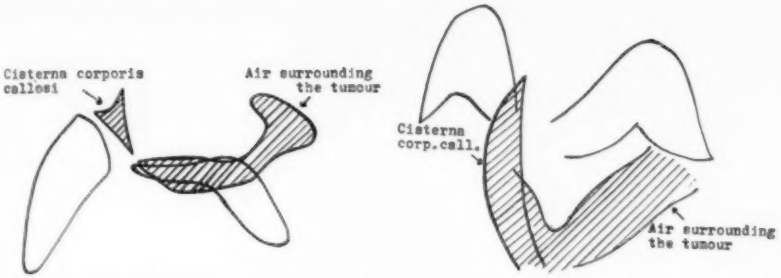


Fig. 10. Unilaterally growing falx meningeoma. Air in the cisterna corporis callosi under the tumour, and surrounding the tumour. (left) P. a. projection. (right) Half-axial projection. (below) Diagrams.

and corpus callosum gliomata. In encephalography, the cisterna is occasionally air-filled without special measures having been taken, but this is not at all the rule. Greater possibilities of intentionally filling the cisterna are afforded by an examination performed in the roentgen department by means of lumbar puncture and with the needle remaining in position. This is the procedure followed as a rule at Serafimer-lasarettet. Under these conditions the air can be directed in an expedient manner with roentgenographic control during the course of its injection.

The conditions in cerebral angiography lie outside the scope of this investigation, but the value of the method in the differential diagnosis between falx meningeomata and corpus callosum tumours will be mentioned briefly. Malignant gliomata and abundantly vascularized meningeomata each exhibit characteristic angiographic signs, due to the appearance of the vessels filled with contrast medium. Furthermore, it is important to determine whether the tumour is supplied entirely or partially

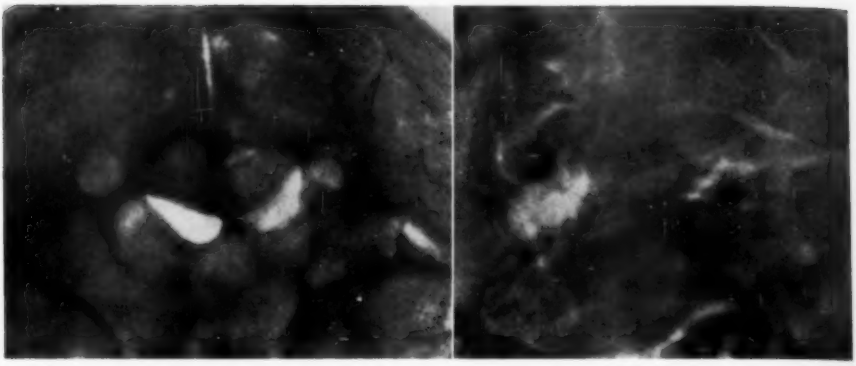


Fig. 11. Glioma of the corpus callosum. Air in the cisterna corporis callosi ending at the posterior limit of the tumour (arrow) by which the cisterna is slightly elevated.

from the external carotid artery. This sign is indicative of a meningeoma. Figure 12 shows angiograms from a falx meningeoma, in which the central parts were filled with contrast medium from the internal carotid artery and the peripheral vessels from the external carotid artery.

Meningeomata of the falx are commonly bilateral, as mentioned earlier. In this material more than half of the tumours grew on both sides of the falx. It has also been stated previously that the majority of the tumours showed marked asymmetry, the tumour on one side of the falx being considerably larger than on the other. These tumours gave rise to practically the same pneumographic appearances as those growing unilaterally. The larger part of the tumour dominates the picture. Under certain conditions, however, it is possible to observe changes caused by the smaller part of the tumour as well. On the side of the smaller part, in these instances, there is a deformation of the lateral ventricle in the form of a small, well-defined impression or a narrow cutting or pinching off of the lateral ventricle. The latter condition occurred in cases in which the tumour grew in under the inferior margin of the falx and over onto the other side.

As already pointed out, it is principally under certain conditions that such local deformation caused by the smaller part of the tumour may be observed in the pneumogram. Among the eighteen tumours in this material growing on both sides of the falx and pronouncedly asymmetric, a deformation of this nature could be demonstrated in only nine cases. Several factors seem to be of significance in this connection. A deformity of this type occurred principally in cases where the smaller part of the tumour was relatively large or deeply seated. Thus, in four of five

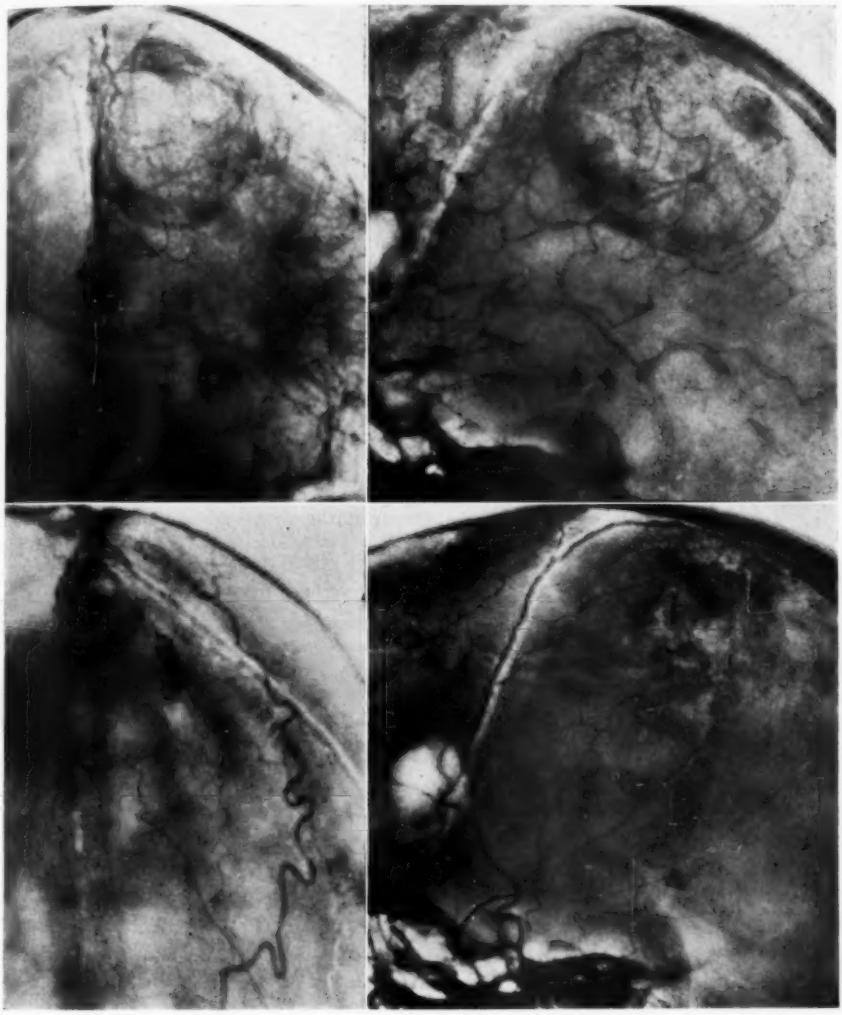


Fig. 12. Cerebral angiography in a case of falx meningeoma. (above) Contrast injection into the internal carotid artery: The peripheral vessels of the tumour are filled. (below) Contrast injection into the external carotid artery: The central vessels of the tumour are filled.

cases in which the tumours grew under the inferior falx margin and over onto the other side, a deformation probably caused by the smaller part of the tumour could be demonstrated. On the other hand, this condition

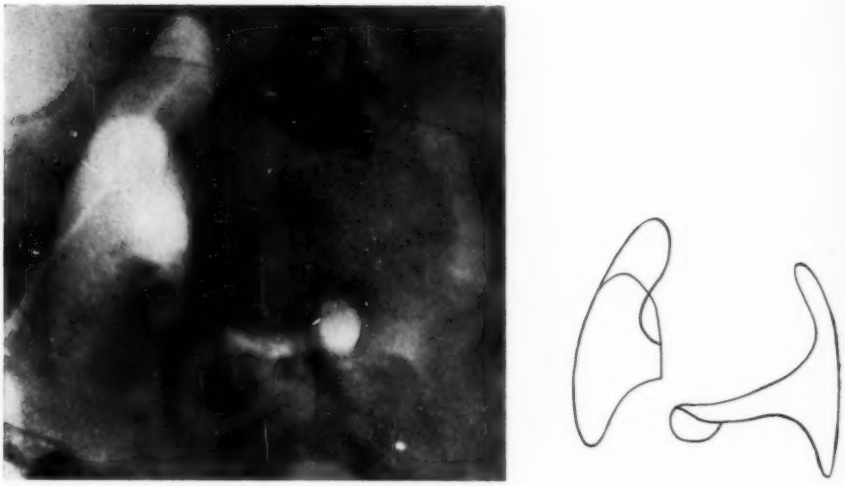


Fig. 13. Half-axial view. Left-sided large parasagittal meningeoma in the posterior third of the sinus. Marked displacement of the left trigone and posterior horn with a well-delimited impression. In the right trigone opposite the tumour, the calcar avis is seen as a small rounded soft-tissue bulge.

occurred in only a few of all the cases in which the tumour grew through the falx without reaching its lower margin. Moreover, it is worthy of note that of the bilateral asymmetric tumours in which the smaller part of the tumour also caused a local deformation of the ventricular system, all were localized to the anterior parts of the falx. As to the posterior parts of the lateral ventricles, the absence of a similar change probably depends upon the divergence of the lateral ventricles posteriorly, where they thus lie farther from the mid line.

The bilateral tumours which originated in the most anterior, narrow part of the falx produced a deformation of both lateral ventricles in almost all cases. This is remarkable, inasmuch as the most anterior part of the falx lies relatively far from the anterior horns. A probable explanation may be afforded by the fact that this was because the tumours situated in this region were all large and that nearly all grew in under the free margin of the falx.

This deformity of the ventricular system which is caused by the smaller part of a bilaterally growing meningeoma of the falx must not be confused with the changes produced by a large tumour in the contralateral lateral ventricle. The latter deformation in general consists of a flattening of the lateral ventricle or of a shallow, long impression. In

this connection, it should be pointed out that the calcar avis can simulate a tumour impression of the above described type in cases of a tumour in the posterior third of the sinus (Fig. 13).

SUMMARY

The pneumographic changes caused by falx meningeoma differ in certain respects from those of other tumours in the vicinity of the falx, such as parasagittal meningeomata lateral to the sinus and gliomata in the corpus callosum. The dissimilarity consists of differences in the deformation of the lateral ventricles and in the displacement of subdural air or air-filling of the cisterna.

Parasagittal meningeomata lateral to the sinus affect the lateral parts of the lateral ventricles to a greater degree than falx meningeomata, which principally depress the medial parts of the lateral ventricles.

The difference in the degree of deformity caused by falx meningeomata and gliomata of the corpus callosum results from the tendency of the latter, but not the former, to grow down into the septum lucidum and into the lateral ventricles. If the cisterna corpus callosi can be filled with air under the tumour the possibility of the latter originating from the corpus callosum may be eliminated.

ZUSAMMENFASSUNG

Die durch Falxmeningeome bedingten pneumographischen Veränderungen weichen in gewisser Hinsicht von denjenigen anderer in der Nähe der Falx gelegenen Tumoren, wie z. B. lateral vom Sinus gelegene parasagittale Meningeome und Glioma im Corpus callosum, ab. Die Abweichungen bestehen in Verschiedenheiten der Deformierung der Seitenventrikel und in der Verschiebung subduraler Luftmengen oder der Luftfüllung der Cisterna.

Lateral vom Sinus gelegene parasagittale Meningeome berühren die lateralen Abschnitte der Seitenventrikel in grösserem Ausmasse als die Falxmeningeome, welche hauptsächlich die medialen Abschnitte der Seitenventrikel hinunterdrücken.

Der Unterschied im Deformierungsgrade, der durch Falxmeningeome und Gliome des Corpus callosum erzeugt wird, beruht auf der Tendenz der letzteren, jedoch nicht der erstgenannten, in das Septum pellucidum hinunter und in die Seitenventrikel hinein zu wachsen. Wenn die Cisterna corporis callosi unter dem Tumor mit Luft gefüllt werden kann, darf die Möglichkeit, dass der Tumor vom Corpus callosum ausging, ausgeschlossen werden.

RÉSUMÉ

Les signes pneumo-encéphalographiques dûs aux méningiomes de la faux diffèrent à certains égards de ceux d'autres tumeurs situées au voisinage de la faux, telles que les méningiomes parasagittaux situés en dehors du sinus et les gliomes du corps calleux: les différences portent sur la déformation des ventricules latéraux et sur le déplacement de l'air sous-dural ou sur le remplissage d'air de la citerne du corps calleux.

Les méningiomes parasagittaux situés en dehors du sinus affectent les parties externes des ventricules latéraux plus que ne le font les méningiomes de la faux, qui dépriment surtout les parties internes des ventricules latéraux.

La différence de degré de la déformation causée par les méningiomes de la faux et par les gliomes du corps calleux résulte de la tendance de ces derniers, mais non des premiers, à croître vers le bas dans le septum lucidum et les ventricules latéraux. Si on parvient à remplir d'air la citerne du corps calleux au dessous de la tumeur, on peut éliminer la possibilité d'un tumeur provenant du corps calleux.

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FROM THE CHILDREN'S HOSPITAL OF WINNIPEG AND THE WINNIPEG GENERAL HOSPITAL, WINNIPEG, CANADA

VENTRICULOGRAPHIC EXAMINATION OF THE AQUEDUCT OF SYLVIUS AND FOURTH VENTRICLE

A Report of Five Unusual Cases

by

Arthur E. Childe, Dwight Parkinson and *Jan Hoogstraten*

Very precise ventriculographic localization of lesions which deform, displace or obstruct the aqueduct of Sylvius and the fourth ventricle should usually be possible, provided sufficient gas is introduced into the ventricular system. We use oxygen as a contrast medium and we feel that the slight extra risk resulting from the injection of a comparatively large quantity of this gas is more than justified by the increased accuracy of diagnosis. Furthermore it is our custom to perform ventriculography early in the morning and to proceed with craniotomy as soon as possible on the same day, should the ventriculographic findings confirm the advisability of such a procedure. Proper positioning and manipulation of the head are essential if the utmost diagnostic information is to be obtained.

The following technic which has been used by us for a number of years has proven quite reliable and it is sufficiently simple that it can be carried out in any department without expensive, additional equipment. The initial part of the examination *always* consists of stereoscopic antero-posterior and stereoscopic lateral 'brow-up' films made with the patient in the supine position. These 'scout' radiographs are routine no matter where the lesion is suspected clinically and they are developed and viewed before anything further is attempted. If they show general symmetrical enlargement of the lateral ventricles but no gas in the third ventricle, further attempts are made to fill this structure. If in addition to dilated lateral ventricles there is a dilated midline third ventricle, it is assumed

that there may well be an obstructive lesion further along in the cerebrospinal fluid pathway. Given these latter conditions, the patient is placed in the prone position, turning the head rapidly so that gas will be trapped in the posterior part of the third ventricle. The head is then lowered over the top or side of the table and it is shaken so that this gas will pass as far caudally as possible. If the ventricular dilatation is marked, suggesting a high degree of obstruction, the shaking is moderately vigorous and prolonged, but if the dilatation is only moderate less agitation is carried out so that the gas will not all be moved past the fourth ventricle. After this the patient is replaced in the prone position on the table and postured, if necessary with pillows under the chest so that the neck is well flexed. Three postero-anterior roentgenograms are then made. For the first the tube is centered low with the central ray directed upward, to project the foramen magnum above the base of the skull. For the second the tube is moved cephalically the usual distance of the stereoscopic shift and for the third the tube is moved again cephalically a similar amount. These three roentgenograms provide two sets of stereoscopic films. Then without moving the patient, stereoscopic 'brow-down' lateral roentgenograms are made, preferably slightly overexposed. To conclude the series ordinary stereoscopic right and left lateral views are taken with the head in the horizontal position.

The following five cases which were all studied in a six month period have been selected to illustrate some of the results of this method of ventriculography.

Case 1. B. D., a five year old male, was examined on August 22, 1951. The complaint was difficulty in walking.

Many café-au-lait spots were noted over the entire body, several of which followed nerve trunk distribution but there were no palpable nodules. These cutaneous manifestations were considered typical of von Recklinghausen's neurofibromatosis. He walked on a broad base. His ears tilted outward markedly, apparently to accommodate an enlarged cranium. The head measured 54.6 cm in greatest circumference. Funduscopic examination revealed a chronic papilledema in both eyes. The remainder of the neurologic examination was within normal limits.

Plain roentgenograms of the skull showed it to be large. The suture lines were somewhat separated and convolutional markings were increased. There was moderate general enlargement of the sella turcica. *Ventriculography* revealed marked general enlargement of the lateral and third ventricles. In spite of adequate positioning and manipulation of the head the aqueduct of Sylvius was filled for only 7 or 8 mm. Proximally it was dilated but its most distal portion was pointed. (Fig. 1.)

Operation: A classic, midline, suboccipital craniotomy was carried out. The cisterna magna, the cerebellum and vermis, and the foramen of Magendie all appeared normal on inspection. When the vermis was split the floor of the fourth ventricle was seen to be covered with nodules which were firm and slightly paler in color than the normal floor. One of them was eventually found to be plugging the aqueduct completely. When the posterior portion of the medullary velum and a part of the collicular plate were split,

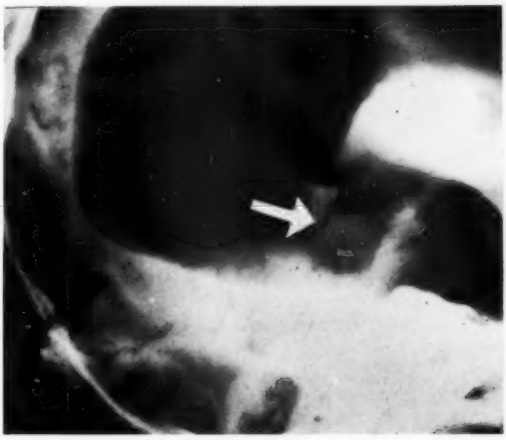


Fig. 1. There is marked enlargement of the lateral and third ventricles. In spite of adequate manipulation of the head no oxygen has passed more than 7 or 8 mm into the aqueduct of Sylvius (arrow).

it was seen that this nodule could be moved fairly freely in its bed. After considerable gentle manipulation it came free and this was followed by a gush of cerebrospinal fluid. The boy had a stormy post-operative course, which was complicated by a spinal fluid fistula. However, this fistula eventually closed and he left the hospital able to walk and feed himself on the thirtieth post-operative day.

Microscopic examination of the nodule removed from the floor of the fourth ventricle showed it to consist of dense, relatively acellular glial tissue containing irregular, somewhat beaded, elongated bodies which stained intensely with eosin, and metachromatic with polychrome methylene blue. The nodule from the aqueduct consisted of similar glial tissue, but it did not contain the eosinophilic bodies. It was felt that the glial nodules were consistent with lesion of tuberous sclerosis.

Comment

A discussion of the relationship between von Recklinghausen's neurofibromatosis and tuberous sclerosis does not fall within the scope of this paper. This case is of interest in that the ventriculogram revealed a complete block in the distal portion of the aqueduct. The lesions encountered in the fourth ventricle at the time of operation were obviously not responsible for these radiographic findings so exploration of the aqueduct was mandatory.

Case 2. B. L., an eleven year old female whose chief complaint was difficulty in walking. She had been considered normal from birth until she attempted to walk. There had been a progressive unsteadiness in her gait from this time until admission. When she was five years of age, it had been noted that her back was crooked.

Examination at the Children's Hospital on July 23, 1951 showed her to be a pale, rather frail looking girl who exhibited a cerebellar type of ataxia with all four limbs. She walked on a slightly broad base. Her reflexes were hyperactive in all extremities, but slightly greater on the left. Pain and temperature sensation were diminished, more

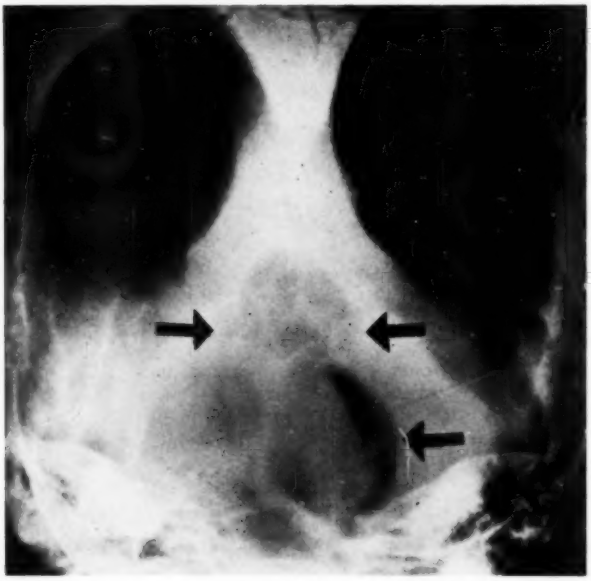


Fig. 2. Both lateral ventricles are markedly enlarged. The upper arrows point to the diverticulum of the right lateral ventricle which is situated in the midline. Only the left side of the fourth ventricle is visualized and a filling defect bulges into it from the right (lower arrow).

markedly on the right than on the left, extending from thoracic 5 to sacral 3 dermatomes. There was no alteration in position or vibratory sense. Funduscopic examination revealed no abnormalities. Taste and the ninth cranial nerve function were not tested but otherwise the cranial nerves were all intact. On the basis of her neurologic examination it was felt that the child had a lengthy, intramedullary spinal lesion as well as a cerebellar lesion.

Plain roentgenograms of the skull showed it to be large, and showed slightly exaggerated convolutional markings. There was no separation of the sutures. The posterior clinoids and the dorsum sellae appeared compressed from above although the remainder of the sella turcica was reasonably normal in appearance. The clivus was concave posteriorly. Roentgenograms of the vertebral column revealed nothing remarkable, other than marked rotoscoliosis convex to the left. *Ventriculography* disclosed that both lateral ventricles and the third ventricle were enormous. The superior and left lateral portions of the fourth ventricle were enlarged but the remainder of it was obliterated by a filling defect which extended well across the midline and had a rounded margin convex to the left. (Fig. 2.) No gas passed beyond the fourth ventricle. There was a midline collection of gas close to the apex of the tentorium, above the fourth ventricle which was interpreted as representing a diverticulum or diverticula of one or both lateral ventricles.

Operation: A classic, midline, cerebellar craniotomy was performed. The cisterna magna was seen to rise unusually high. Immediately beneath the cisterna magna there was a cystic mass. When this cyst was opened the next structure below appeared to be a normal floor of the fourth ventricle and it was possible to look upwards and visualize the aqueduct. Looking caudally, however, no normal obex could be seen and it appeared that the cystic cavity extended down into the spinal cord. The cyst was marsupialized to the subarachnoid space and the wound closed. The patient was out of bed walking on

the second post-operative day, but shortly thereafter developed a fever, became progressively worse, and died on the fifth post-operative day.

Autopsy showed that the lateral and third ventricles were greatly enlarged and that their walls were covered with a thick, greyish, shaggy exudate, quite evidently inflammatory in nature. There was a diverticulum arising from the floor of the right lateral ventricle and extending in a posteromedial direction so that it lay close to the apex of the tentorium in the usual location of the cisterna ambiens. A cyst measuring $4.3 \times 2.5 \times 1$ cm replaced most of the inferior part of the right cerebellar hemisphere and practically all of the inferior vermis and it extended across the midline for about 0.5 cm into the left cerebellar hemisphere.

The entire spinal cord had a soft, cystic consistency. Longitudinal sections revealed it to be a more or less hollow tube the lumen of which was formed by many irregular, cystic cavities separated by septa 1 or 2 mm in width. This cavitation began in the cervical region and extended through the thoracic cord where the cystic formation was very marked to the lumbar segments where the cyst formation was at an earlier stage of development. There was no connection between the cerebellar cyst and the cysts of the cord. *Microscopic examination* revealed no evidence of gliomatous changes in the central nervous system.

Comment

In this case the preoperative diagnosis of a diverticulum of the lateral ventricle was not difficult. It was originally felt that the filling defect which bulged into and obstructed the fourth ventricle might be a continuation of syringomyelic dilatation of the spinal cord. The presence of a solitary, innocent cerebellar cyst, and multiple spinal cord cysts came as a surprise. Had infection not resulted, the hydrocephalus might have been arrested, but the cord lesions would presumably have progressed gradually.

Case 3. K. M., a twenty month old male was admitted to the hospital because of progressive weight loss, irritability and neck retraction.

Examination showed him to be a listless, apathetic, thin, pale, white child, whose attempts at walking were grossly ataxic. Funduscopic examination revealed no abnormality except for rather pale discs.

During his stay in the hospital, he had several episodes of extensor rigidity, or so-called 'cerebellar fits'. Plain roentgenograms of the skull showed slight separation of the sutures. *Pneumoencephalography* failed to visualize the ventricular system. There was some oxygen in the interpeduncular and pontine cisterns and also between the anterior portions of the cerebral hemispheres. The distribution of this interhemispheral gas suggested dilatation of the lateral ventricles. *Ventriculography* four days later revealed marked general enlargement of the lateral and third ventricles. The aqueduct of Sylvius was short and broad. There was striking enlargement of the fourth ventricle posteriorly and to the right but most of it was filled with a soft tissue mass which originated from the left side although it bulged far across the midline to the right. Considerable oxygen had entered the cisterna magna but none passed into the upper cervical region. (Fig. 3.)

Operation: Under general anaesthesia, a classic midline cerebellar craniotomy was performed. Upon opening the dura, considerable tumor tissue was found in the cisterna magna. This extended down to the level of the second cervical vertebra as a long, free tongue attached on one margin, however, to the vertebral artery and it extended upward

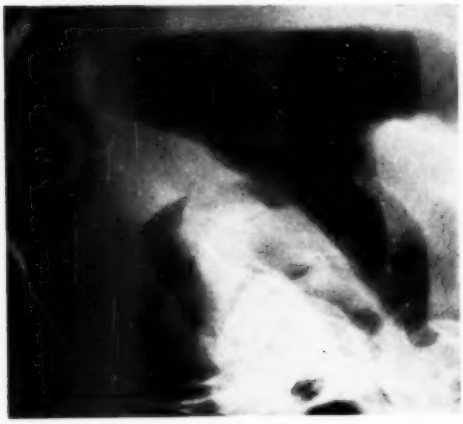


Fig. 3. A large filling defect can be seen extending into the fourth ventricle. In spite of this considerable gas has been shaken through into the cisterna magna.

through the greatly enlarged foramen of Magendie. As the vermis was split, a large mass of tumor tissue was found in the fourth ventricle, particularly posteriorly and on the left side. This tumor separated out easily from the floor of the fourth ventricle and from its right side, but one tag was seen to extend up into the aqueduct, which it completely plugged. There was no actual attachment of the tumor tissue at this site and it was removed by gentle teasing which allowed a free gush of cerebrospinal fluid through the aqueduct. The immediate post-operative course was quite satisfactory but on the third post-operative day, the patient developed an upward and outward spasmodic movement of the right eye. Shortly thereafter he had marked difficulty in swallowing, and in spite of all supportive treatment died on the fourteenth day.

Microscopic examination of the removed tumor showed it to be an astrocytoma. Subsequent *autopsy* revealed that the tumor had not only extended into the fourth ventricle, aqueduct and foramen of Magendie, but that it had also extended through both foramina of Luschka. These latter portions of the tumor had not been removed at the time of operation. The mass protruding through the left recess was the larger and it covered an area 4.5×5 cm on the lateral and anterior surfaces of the cervical cord, medulla and pons. The tumor on the right side bulged through the lateral recess for 1 cm. The total weight of the remaining tumor was 30 gm.

Comment

Although there was a large tumor mass in the fourth ventricle, at the time of ventriculography this did not obstruct completely the aqueduct or the foramen of Magendie, for oxygen was made to pass into the cisterna magna. The extensions of this tumor through the lateral recesses were unsuspected. If the floor of the fourth ventricle had not been obscured by the neoplasm it might well have been found to be displaced posteriorly away from the clivus.

Case 4. W. X., a forty-seven year old white male was admitted to the Winnipeg General Hospital on October 2, 1951. Six days previously he sustained a head injury which rendered him unconscious for four hours. Recovery at first seemed fairly complete

Fig. 4. There is very little enlargment of the lateral ventricles. The fourth ventricle is small and displaced 6 mm to the right of the midline (arrow).

but three to four days later, he developed progressive headache, vertigo, ataxia, nausea and vomiting. Examination revealed a co-operative, strongly built, middle aged man, who was completely unable to walk without support. He had a generalized hyper-reflexia, more marked on the left and he constantly fell to the right if held upright. Funduscopic examination revealed no abnormalities other than rather marked fullness of the veins. There was minimal incoordination of the left hand.

Plain roentgenograms of the skull disclosed no fracture. Subsequent *ventriculography* showed the lateral and third ventricles to be only slightly enlarged but not otherwise remarkable. The fourth ventricle was displaced 6 mm to the right of the midline. It was not completely obstructed as some oxygen had passed through it into the upper cervical region. (Fig. 4.)

Operation: Following ventriculography, a midline suboccipital craniotomy was performed. There was a fairly extensive subdural collection of clotted and dark liquid blood over the left cerebellar hemisphere. When this was removed, a small tear could be seen in the medial portion of the left cerebellar lobe through which more blood clot projected. As this opening was enlarged, it was found to extend into a cavity approximately 1 cm in greatest diameter which contained a clot of the same consistency as that found subdurally. This was irrigated clean. The patient made a most dramatic recovery. He was up walking on the second post-operative day and within one week was walking without the slightest evidence of ataxia. He has returned to hard manual labor, which he has been able to perform as well as he could before his injury.

Comment

Significant features in the diagnosis in this case were recent trauma and subsequent severe cerebellar ataxia. The tremendous neurologic disturbance associated with minimal enlargement of the lateral and third ventricles and only moderate displacement of the fourth ventricle suggested a cerebellar lesion of recent origin, occupying a comparatively small amount of space. Consequently the diagnosis of cerebellar hematoma was made pre-operatively.

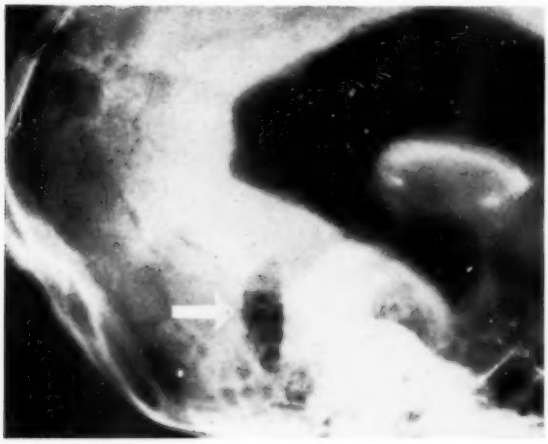


Fig. 5. The lateral and third ventricles are considerably dilated and so is the proximal part of the aqueduct of Sylvius. There is also partial visualization of a dilated fourth ventricle but no gas has passed into the cisterna magna or upper cervical region.

Case 5. (This case has been published in more detail in the Journal of Neurosurgery, 9: 404—408, July 1952.) M. L., a twenty-eight-year old white male had been well until eight weeks before he came under observation. He first noticed a feeling as though ants were crawling over his left occiput and within the next day or so he began to stagger and his vision became blurred. Vomiting commenced four weeks later, but no serious headache developed.

Examination showed a haggard appearing young man who preferred to lie in a curled-up position in bed. He walked with an ataxic gait. There was acute bilateral papilledema and there was a fine rapid nystagmus on lateral deviation, most marked to the right.

Ventriculography outlined symmetrically dilated lateral ventricles and a dilated midline third ventricle. The aqueduct of Sylvius was also greatly dilated measuring 5 mm in diameter, but in spite of adequate manipulation of the head it was visualized only in its proximal 5 mm. In addition there was partial visualization of a considerably enlarged fourth ventricle which was situated in the midline. (Fig. 5.) These findings were interpreted as indicating a lesion which was obstructing the foramina of Luschka and Magendie and which was also extending up into and partially obstructing the aqueduct of Sylvius.

Craniotomy the same day showed that both cerebellar tonsils extended down to the inferior edge of the arch of the atlas. When they were separated, a smooth walled, fluctuant, blue-gray mass resembling a nasal polyp was seen protruding through the foramen of Magendie. This had no apparent attachment and was gently teased out, although its wall broke during delivery releasing homogeneous fluid. When re-expanded it measured 1.5 cm in diameter. After it had been removed it was found that another similar cyst about 1 cm in diameter had taken its place. This second cyst was easily extracted without rupture and there was then a free gush of cerebrospinal fluid from above. Subsequent exploration of the entire fourth ventricle after splitting the vermis showed no other cysts and the aqueduct allowed the passage of a + 8 French catheter into the third ventricle. No point of attachment was visible in the fourth ventricle and there was no roughening on the surface of either cyst which could have represented a point of attachment.

The patient made an entirely satisfactory recovery and when last seen four months

later he was working as a laborer in the woods. He had gained 25 pounds and his nystagmus and papilledema had disappeared.

Microscopic examination of each cyst wall revealed a lining of columnar ciliated epithelium with an enveloping layer of fibrous stroma. Grossly and microscopically the two cysts were identical with the typical colloid cyst of the third ventricle. Although it is possible that they originated in the third ventricle and washed down through the aqueduct in their infancy, it seems more likely that they originated in the fourth ventricle.

Comment

This case is interesting not only because of the rarity of the lesion but also because of the complete post-operative recovery. Ventriculography indicated that there was partial obstruction of the aqueduct of Sylvius as well as additional obstruction involving the foramina of the fourth ventricle. Preoperatively an elongated lesion situated in the fourth ventricle and extending up into the aqueduct was considered more likely than multiple lesions, but although this premise was sound, it proved incorrect.

SUMMARY

A useful, simple technic of ventriculographic examination for lesions which deform, displace or obstruct the aqueduct of Sylvius and fourth ventricle has been presented.

The ventriculographic findings are described in five illustrative cases. Each case presented unusual features which were demonstrated satisfactorily by this method and confirmed by surgery.

ZUSAMMENFASSUNG

Eine einfache ventrikulographische Untersuchungstechnik für Schädigungen, die den Aquaeductus Sylvii und den IV. Ventrikel deformieren, verschieben oder ausfüllen, wird vorgelegt. Die Ventrikulographiebefunde werden in 5 illustrativen Fällen beschrieben. Jeder Fall zeigte ungewöhnliche Züge, welche mit dieser Methode zufriedenstellend demonstriert und chirurgisch bestätigt wurden.

RÉSUMÉ

Les auteurs présentent une technique simple et utile d'examen ventriculographique des lésions qui déforment, déplacent ou obstruent l'aqueduc de Sylvius et le quatrième ventricule. Ils décrivent les signes ventriculographiques dans cinq cas pris à titre d'exemple. Chacun de ces cas présentait des particularités inhabituelles qui ont été mises en évidence de façon satisfaisante par cette méthode et qui ont été confirmées à l'opération

FROM THE ROENTGEN DEPARTMENT (DIRECTOR: PROFESSOR ERIK LINDGREN),
SERAFIMERLASARETTET, STOCKHOLM, SWEDEN

ENCEPHALOGRAPHY IN CASES OF INTRACRANIAL TUMOUR

by

Bengt Falk

The pneumographic method of examination of the brain in cases of suspected tumour has proved of immense and undisputed value. However, there appears to be a difference of opinion as to whether the examination should be performed by injection of air directly into the lateral ventricles through burr-holes in the skull or through the orbits, or by encephalography with injection of air via the subarachnoidal space by lumbar or suboccipital puncture. One or other of these methods is repeatedly recommended in the many papers on the subject published every year, but the statements and results seem to be contradictory and indefinite so that in trying to form an opinion from the literature one is often only confused.

The risks of ventricular puncture are well known and recognized: damage to the brain tissue, especially if several punctures are required — as is often the case when the lateral ventricles are displaced, intracranial bleeding, and other immediate consequences. There are also late complications. As I have shown some years ago, calcifications in the track of the needle or beneath the burr-holes ensue some time after ventriculography in more than ten per cent of cases, indicating permanent injury. Such complications are completely avoided by encephalography and it would, therefore, be better if this method of examination could always be used. There are two main objections against the encephalographic method in cases of brain tumours. The first is the danger of foraminal herniation through increased intracranial pressure, and the second is that in certain cases air does not enter the ventricles, with consequent poor diagnostic results.

I feel, however, that these two objections are based on the use of a wrong technique. There are, of course, many different encephalo-

graphic techniques and the method in general should be judged from the best. Incidentally, certain encephalographic examinations sometimes reveal more about the examiner than about the patient.

Judging from the encephalographic method, as designed and used in the Roentgen Department of Serafimerlasarettet, the results are very good. In most cases it gives more information about the lesion than does ventriculography, and the risks for the patient are not increased, providing the necessary precautions are taken.

Although our technique has previously been described in detail, I think it is necessary to give a short survey. The air is injected by lumbar puncture with the patient in a sitting position. The neck is extended and the head is bent slightly forwards with the chin back. When the puncture is made, a small amount of air, say 5—10 cc is slowly injected before any fluid is removed. One or two lateral films are then taken. The following advantages are obtained by injecting air first: The air enters the fluid spaces more easily because the narrow passages are better distended if the fluid pressure is not allowed to decrease. If no fluid is removed before injecting air, the pressure in the spinal canal is, if anything, increased, thus preventing a pressure cone during the examination; this is of the utmost importance.

The procedure following the first air injection depends upon what is seen on the first films. If the air enters the fourth ventricle and passes through the aqueduct we inject more air, and fluid may now be removed although less fluid is always removed than air injected. If the air does not enter the ventricular system the first films will, nevertheless, show if it is going forwards into the pontine cisterns or backwards into the cisterna magna. In the former case the head is bent further forwards and in the latter further backwards, before more air is injected. With this procedure, which can if necessary be repeated, the air may be directed to the ventricles; when these are sufficiently filled more air is injected and directed to the different cisterns which are to be investigated. The total amount of air used varies greatly, depending chiefly upon the width of the lateral ventricles. In normal cases it is about 20—25 cc, 15 cc for the ventricular system and 10 cc for the convexity. When the injections are made and all the necessary views in the sitting position taken, the patient is lain down and the investigation proceeds according to both the findings on the films and the clinical history. In order therefore to achieve the object of correct diagnosis, the roentgen examination must be carried out by an operator who understands all aspects, both of the technique and interpretation of the films.

By this method, more than 1,800 patients were examined during the years 1948—1951. A survey of our experiences, stressing certain points of special interest follows.

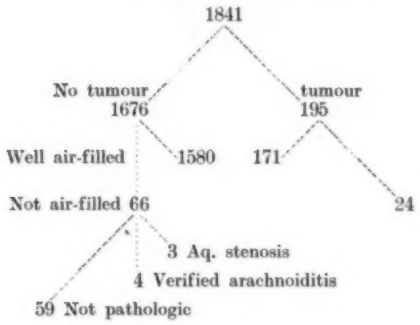
First, a summary of the cases:

Total number of encephalographies 1948—1951		1,841
Intracranial tumours	196	
Subfrontal	7	
Frontal	18	
Parietal	17	
Occipital	5	
Temporal	29	
Central	18	
Sellar or suprasellar	65	
Posterior fossa	37	

In 90 cases, no air could be made to enter the ventricles. These were divided as shown in Table 1.

Table 1

Total number of encephalographies



Good air filling was thus obtained in 95.1 % with or without tumours.

Of the 90 cases not air filled, no pathologic changes could be found in 59 on further roentgen examination, but 6 had a history of meningitis or encephalitis, 1 had syphilis, 4 had had skull fractures, 1 subarachnoidal bleeding, 2 severe delivery trauma, 1 had a basilar impression and one assimilation of the atlas, which may well have been the causes of air not entering the ventricles in these cases. If we subtract those 16 cases, 43 are left out of 1,676, *i. e.* 2.5 per cent of normal cases in which air did not enter the ventricles. We know, however, that the foramen Magendie may sometimes be absent and sometimes represented by only a narrow channel, and this anomaly probably accounts for some of the cases that were not air filled.

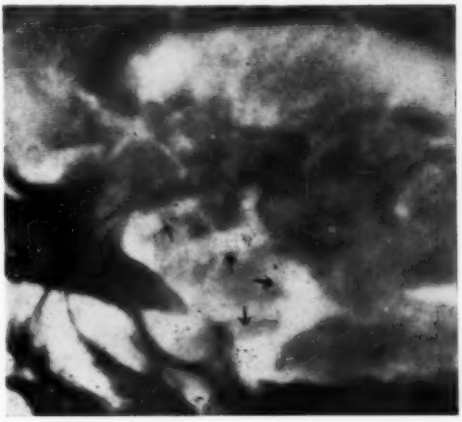


Fig. 1. Meningioma from the sphenoidal plane. The tumour is surrounded by convexity air and goes back well behind the sella.

Of special interest are the 24 tumour cases in which no air entered the ventricles (Table 2). The existence or not of a tumour could not be determined in only three cases. In 7 cases, the extracerebral air alone was sufficient for exact tumour localisation. Of the 37 infratentorial tumour cases in the material, encephalography alone was sufficient for diagnosis in 23. In several of the 12 cases in which ventriculography was carried out, it was necessary to combine this with encephalography in order to make the diagnosis definite.

Table 2

No air in the ventricles: 24 tumour cases

	Supratentorial	Infratentorial	Total
Diagnosis definite from encephalography	5	2 =	7
Tumour diagnosis definite but ventriculography or angiography indicated for exact localisation	2	12 =	14
Tumour diagnosis uncertain. Ventriculography or angiography necessary for diagnosis	1	2 =	3
Total	8	16	

From a purely technical roentgenologic viewpoint, encephalography has the advantage over ventriculography that the air on the convexity and in the cisterns can be of valuable help in diagnosing expanding lesions. This advantage is not so great in convexity tumours: too much air on the convexity may in some cases be a hindrance, especially by concealing small changes in the temporal horn. The examiner has therefore to arrange for the right amount of air on the convexity in the

Fig. 2. The tumour is very distinctly outlined by cisternal air and must therefore be extracerebral. — Suprasellar meningioma.

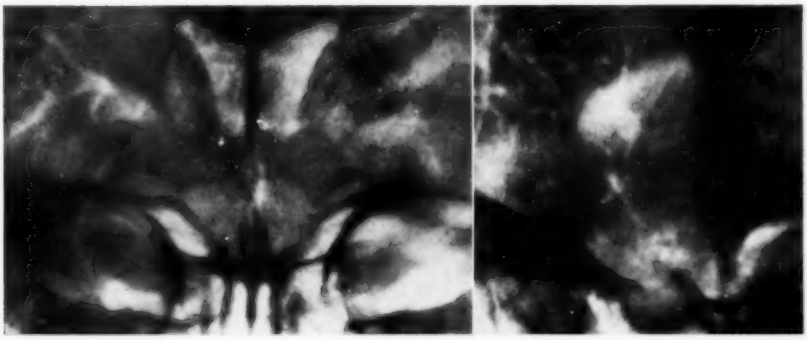


Fig. 3. Meningioma from the sphenoidal ridge. The intracranial size of the tumour can be only partly judged by the slight displacement backwards of the temporal horn (↔). Convexity air (→) lying directly above the tumour enables exact determination of its extent.

particular case. Extracerebral expanding lesions, especially those situated basally, may in many cases be completely outlined by subarachnoidal air, which gathers round the tumour, enabling a diagnosis of type in addition to accurate localisation. (Figs. 1—3).

In tumours of the sellar region, air on the convexity and in the basal cisterns is of particular value. In small tumours the ventricular system and even the third ventricle may not be altered at all, the only indication being a deformity of the cisterns above the sella.

Fig. 4. Chromophobic adenoma surrounded by air in the basal cisterns. The infundibular recess of the third ventricle is a little flattened, although the alteration is slight.

Fig. 5. Large tumour in the anterior part of the third ventricle. Cisternal air, however, surrounds the stalk the whole way down to the sella and the tumour must therefore be an adenoma.

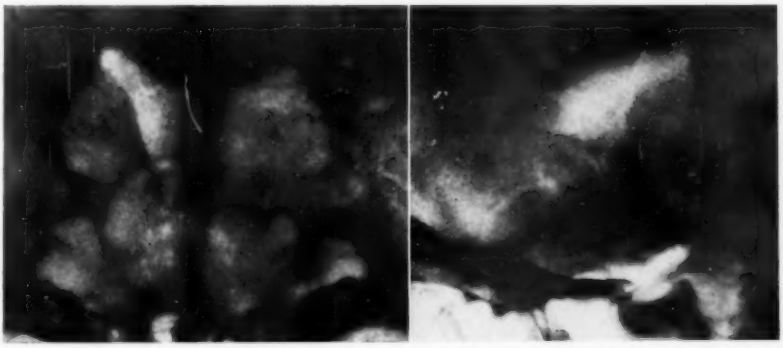


Fig. 6. Intracerebral, suprasellar tumour — subfrontal glioma. The changes in the lateral ventricles are small. The tumour is compressing the cisterns from above, pushing them against the sellar entrance.

In other cases we can differentiate between intrasellar tumours growing up above the sella, suprasellar extracerebral, and suprasellar intracerebral tumours. Even in those cases in which no filling of the ventricular system is obtained, an examination of the cisterns may

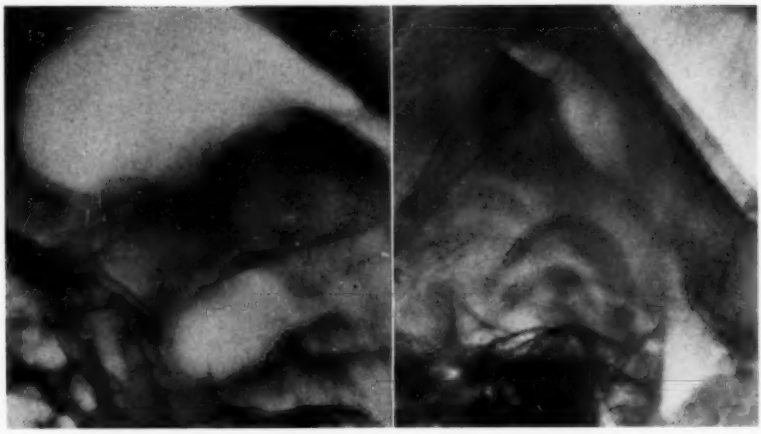


Fig. 7. On ventriculography (left) no air could be passed from the lateral ventricles to the third ventricle. This examination alone might perhaps have given the impression of an inoperable tumour in the third ventricle. But on encephalography (right) air passed quite easily through the third ventricle, which was pushed up. In its lower portion the upper pole of a large suprasellar tumour is seen; at operation this was found to be a craniopharyngioma.

give enough information about the position and size of the tumour. (Figs. 4—6.)

Central tumours, in the third ventricle or its vicinity, may obstruct the fluid passage and thus cause a dilatation of the lateral ventricles. In our experience it is more difficult to force air from the lateral ventricles through the foramen of Monro into the third ventricle than in the opposite direction.

Thus accurate diagnosis of these blocking central tumours is easier with encephalography than with ventriculography. (See figs. 7—9.)

In all such cases ventriculography alone may give the impression of a tumour in the third ventricle with complete block of the foramen of Monro, but no more information. By encephalography, however, the third ventricle may be studied and better localisation made possible; in our experience it is preferable to carry out encephalography first, as this examination usually gives more information than ventriculography.

Small central tumours, which are not causing blocks, are also easier to detect with encephalography because better air filling of the posterior part of the third ventricle and the aqueduct is obtained (fig. 10).

With regard to examination of the posterior fossa, the encephalographic method, in many cases, has certain great advantages over

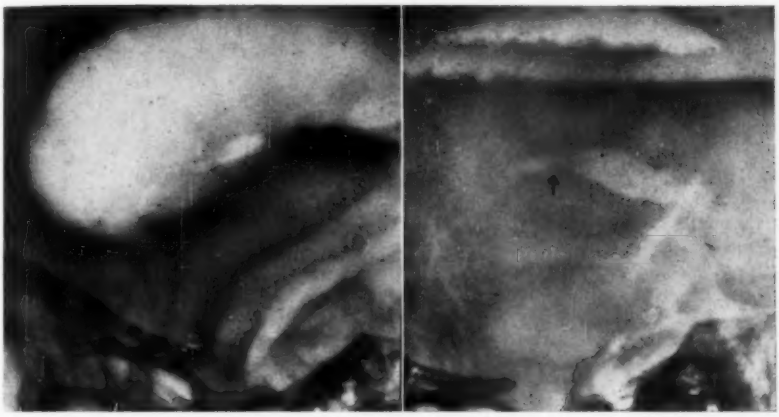


Fig. 8. On ventriculography (left) no air entered the third ventricle, which, however, was filled on encephalography (right) and the tumour — an optical glioma — clearly seen. (From the encephalographic viewpoint the optical gliomas show, as a rule, the same changes as certain true extracerebral tumours.)

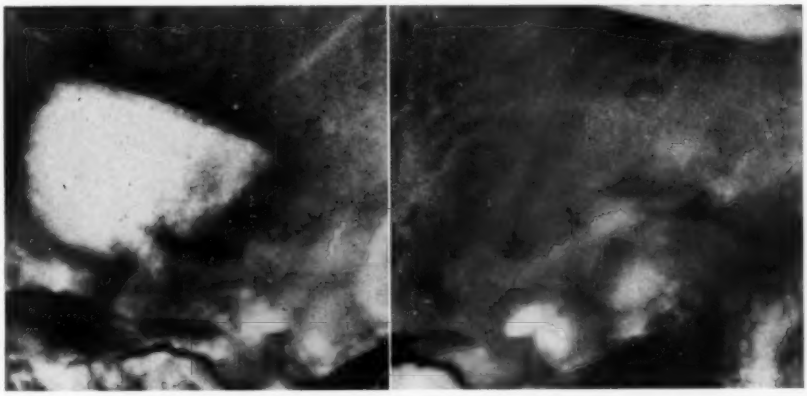


Fig. 9. Cyst in the foramen of Monro. Soft tissue density bulging from above into the upper part of the 3rd ventricle at the foramen of Monro (arrows). The air is passing through to the lateral ventricles.

ventriculography. The fourth ventricle and the aqueduct are more easily visualised in films taken when the air is passing upwards and the patient is in a sitting position, than when the filling is carried out from above as in ventriculography.

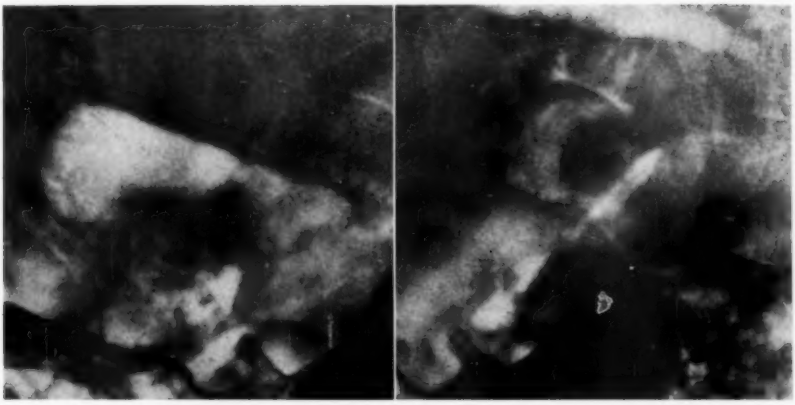


Fig. 10. Small pinealoma, blotting out the recesses and bulging into in the posterior part of the 3rd ventricle (right). There is also some backward displacement of the anterior part of the 3rd ventricle, probably due to ectopic pineal tissue (left).

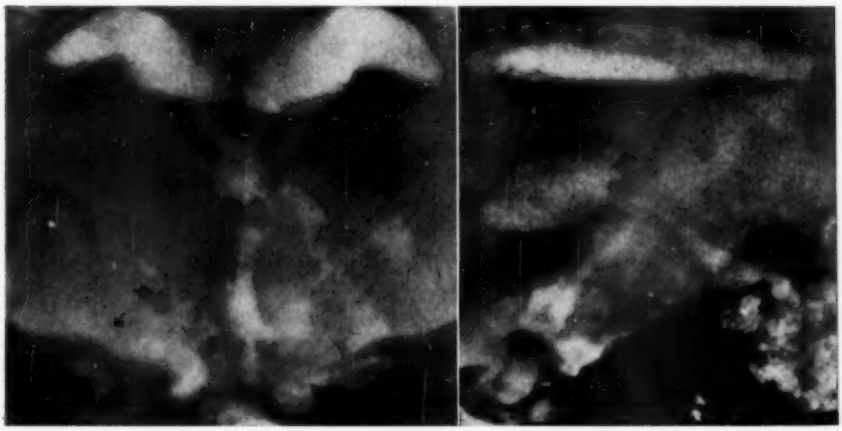


Fig. 11. Acoustic neurinoma with no changes in the ventricles nor displacement of the aqueduct. Diagnosis possible only through study of the cisterns. On the left side, there is a normal cerebello-pontine cistern and good air-filling of the ambient cistern. On the right side, however, the air remains in the medial part of the cistern and laterally there is a filling defect caused by the tumour (arrow).

The greatest advantage of the encephalographic method, however, is that it gives us an opportunity of examining the extracerebral fluid spaces in the posterior fossa. Thanks to the involved, but well-defined anatomy of the posterior fossa, these extracerebral spaces have a very

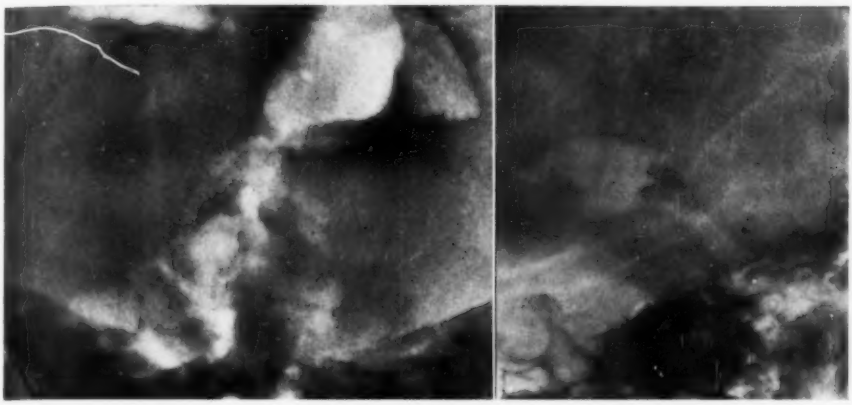


Fig. 12. Displacement of the aqueduct and 4th ventricle to the right. The cisterns on the right side are normal but on the left side there is a big filling defect laterally. The tumour is thus extracerebral — an acoustic neurinoma.

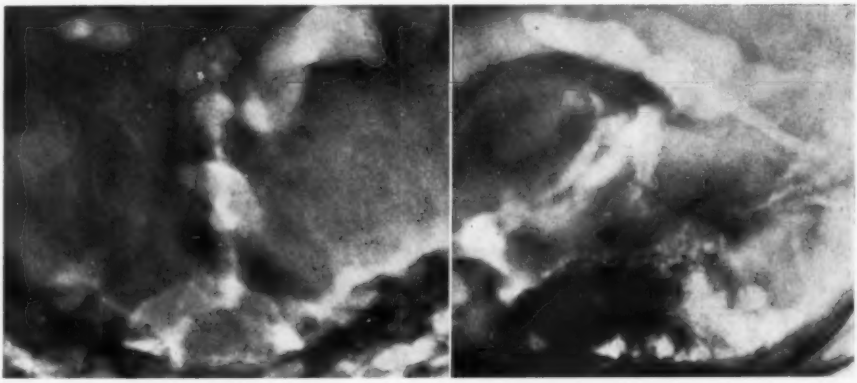


Fig. 13. Vallecula is slightly dislocated to the left and there is a tilt and an indentation of the 4th ventricle from the right. A narrow strip of air is seen along the pyramid, past the internal auditory meatus and tumour is thus intracerebral (metastasis).

constant appearance. Thus even small changes in their form can be detected and used in the diagnosis of expanding processes. In this way it is even possible to see tumours which are so small that they cause no displacement or deformity of the fourth ventricle or aqueduct and no dislocation of the vallecula. (Fig. 11.)

Even when the fourth ventricle and aqueduct are affected, study of the extracerebral cisterns makes much more exact localisation pos-

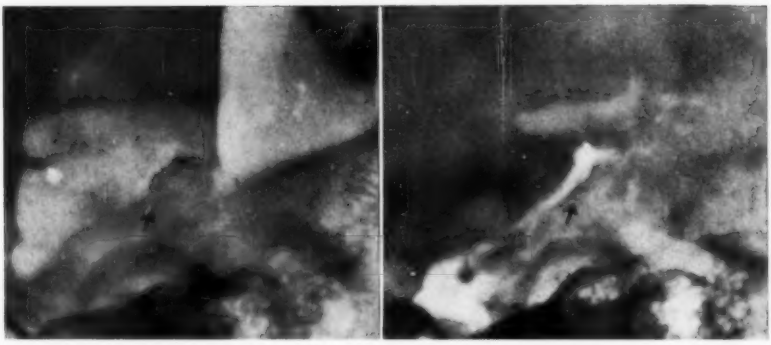


Fig. 14. Relative stenosis of the aqueduct. In the sitting position (right) the aqueduct is filled as high as arrow. Air in the cisterns above the quadrigeminal plate, which is normal. Air passes up into the wide lateral ventricles. In the prone position (left) only the first mm of the aqueduct if filled (arrow) and no air could be made to pass in this direction from above into the 4th ventricle; it would therefore have been impossible to exclude a tumour by ventriculography only. If we combine both films, there is a small length of the aqueduct (1—2 mm) which cannot be air filled (stenosis).

sible and often enables us to distinguish between extra- and intracerebral tumours. (Fig. 12—13.)

In the same way it is possible to distinguish between intrapontine tumours and meningiomata from the clivus, both of which may cause similar displacement of the aqueduct and fourth ventricle.

The diagnostic opportunities are most favourable in cases when air enters the ventricles, but even when these cannot be filled, correct diagnosis may sometimes be made by changes in the cisterns alone.

In other cases, when air does not enter the ventricles, encephalography informs us that a tumour in the posterior fossa is actually present although ventriculography may be necessary for its exact localisation.

Encephalography may also be of great value in cases of inflammatory stenosis of the aqueduct. (Fig. 14.)

It is clear that no pneumographic method can be absolutely without risk. Every air-filling of the intracranial subarachnoidal space is accompanied by some degree of headache and nausea, but this is no real complication and will therefore not be discussed.

Real complications are uncommon. As the air is injected first, no herniation occurs during the roentgen examination. But there is always the risk that fluid may leak out through the puncture hole after the examination — thus diminishing the pressure in the spinal canal and

causing coning. Encephalographic examination of tumour cases with increased intracranial pressure must therefore be performed only in hospitals in which the patient can be operated upon if necessary.

Since complications are more likely to occur in cases of tumours of the posterior fossa and in which air often does not enter the ventricles, the following procedure is recommended. When there is clinical suspicion of subtentorial or central blocking tumours, or definite signs of high intracranial pressure, the encephalography is preceded by the making of burr-holes as for ventriculography.

The encephalography is carried out with great care. There must be no fluid removal and only small amounts of air injected. If no air enters the ventricular system and the shape of the cisterns does not give the diagnosis, ventriculography is performed at the same time, using the already existing burr-holes. In this way we do not lose the great advantages of studying the extracerebral fluid spaces in the posterior fossa, while maintaining the possibility of performing a ventriculography without further delay. Furthermore, should a pressure cone occur, ventricular puncture can be made at once, thus diminishing the risk of the examination.

In the whole material there were only six patients who had herniation attacks following the examination. In two of them the symptoms subsided without treatment, in three cases immediate operation was performed and recovery ensued. In the last case the encephalography revealed a tumour in the posterior fossa, but for complete localisation a ventriculography was performed the same day. During this examination the patient developed a herniation and died, in spite of a ventricular puncture having been made immediately. She was in bad condition and had a pontine glioma.

I must add that in fourteen of the supratentorial tumours I have been unable to study the complete history of the patients and cannot, therefore, positively exclude other complications. However, the close cooperation existing between the staffs of the different departments would certainly have ensured attention being drawn to any serious complications.

I have not entered into any discussion of encephalography in comparison with angiography. In order to obtain good results both methods are indispensable and augment each other. The neuroradiologist must master them both. The choice between, and the order of, the different methods of examination must be made in close cooperation with the neurosurgeon and the neurologist.

I feel I have answered the two main objections against encephalography in this survey: that often the air does not enter the ventricles,

and that the method is too risky. With the correct technique, the complications are few and the diagnostic results are so good that they justify the small risks involved.

SUMMARY

The author discusses the pneumographic method of examining the brain in cases of suspected tumour and points out the complications which may arise following ventriculography. Encephalography demands a careful technique and the one employed in the Roentgen Department of Serafimer Lasarettet is described. An analysis of some 1,850 cases examined by means of encephalography during the period 1948—51 is presented and discussed. In certain special cases a combination of encephalography and ventriculography is recommended. The conclusion is reached that the diagnostic results of encephalography are so excellent that they outweigh the small risks.

ZUSAMMENFASSUNG

Es werden die Methoden zur Luftfüllung des Ventrikelssystems bei Fällen mit Verdacht auf Hirntumor besprochen und es wird auf die Komplikationen hingewiesen, die im Gefolge einer Ventriculographie (Luftfüllung nach Ventrikelpunktion) auftreten können. Die Luftencephalographie (lumbal) erfordert eine subtile Technik. Es wird die auf der Röntgenabteilung des Serafimer-Krankenhauses übliche Technik beschrieben. Es werden 1,850 Fälle, die in den Jahren 1948—51 mittels Luftfüllung untersucht wurden, kritisch ausgewertet. Für gewisse geeignete Fälle wird eine Kombination von Encephalographie und direkter Ventrikelfüllung empfohlen. Der Verfasser kommt zu dem Ergebnis, dass die ausgezeichneten Ergebnisse der Encephalographie wohl das relativ geringe Untersuchungsrisiko aufwiegen.

RÉSUMÉ

L'auteur étudie l'application de la méthode pneumographique à l'examen du cerveau dans les cas ou l'on soupçonne une tumeur et insiste sur les complications qui peuvent survenir à la suite de la ventriculographie.

L'encéphalographie exige une technique rigoureuse; l'auteur décrit celle qui est employée dans le Service de Radiologie de Serafimerlasarettet. Il présente et commente l'étude analytique d'environ 1,850 cas examinés par encéphalographie dans la période 1948—51. Dans certains cas spéciaux, il est recommandé de combiner l'encéphalographie et la ventriculographie. On arrive à la conclusion que les résultats diagnostiques de l'encéphalographie sont si remarquables qu'ils l'emportent sur les petits risques qu'elle fait courir.

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FROM MAIDA VALE HOSPITAL (THE NATIONAL HOSPITALS FOR NERVOUS DISEASES), LONDON, ENGLAND

RADIOLOGIC ASPECTS OF PONTINE GLIOMATA

by

David Sutton

It would appear from the work of LYSHOLM as published in 1935, 1941 and in his last work in 1946 that a radiologic syndrome based on pneumography exists for the diagnosis of pontine tumours. He states, however, that his total number of verified cases on which these views were founded was only eleven, though he had seen a larger number of unverified cases in which a presumptive diagnosis of pontine tumour was made.

As a result of some personal experiences with cases of pontine tumour which did not appear to fit in completely with the picture described by LYSHOLM, the writer was led to attempt a review of cases of this kind and of their differential diagnosis.

Seventeen cases, all verified at autopsy and submitted to adequate radiologic investigation have been collected and analysed, and the results are here briefly presented. About three quarters of the cases were examined histologically.

The types of tumour most commonly encountered were astrocytomata of varying grades. Some cases were defined as spongioblastomata. According to the literature, it is quite irrelevant what type of tumour is present. The prognosis is equally bad whether the growth is slow-growing or highly malignant. This was so in all this series of 17 proved cases, in which the average expectation of life was about six months, nearly all the cases dying within a year.

It is proposed to consider the radiologic aspects of pontine gliomata under the following headings:

(1) Ordinary roentgenography.
(2) Pneumography and positive contrast ventriculography.
(3) Vertebral angiography.

1. Ordinary Roentgenography

It is a clinical fact that evidence of greatly raised intracranial pressure is unusual with pontine tumours. A study of the ventriculograms in these cases shows that hydrocephalus, if present, is usually of a very mild degree, and may be completely absent, the aqueduct or fourth ventricle remaining patent despite the presence of a very large tumour.

The ordinary roentgenograms therefore are nearly always within normal limits in cases of pontine glioma. This was so in almost every case in this series.

In a few exceptional cases, however, more definite obstruction to the aqueduct or fourth ventricle may develop, and a more severe hydrocephalus ensue. Several such cases have been recorded in the literature — BASSOE and APPELBACH (1925), HARE and WOLF (1934), ECHOLS (1938), but we may accept the fact that it is most unusual for ordinary films in a case of pontine glioma to show anything but a normal skull, and that radiologic evidence of greatly raised intracranial pressure, whilst it does not exclude the possibility of a pontine tumour being present, is far more likely to be due to some other lesion.

ALPERS and YASKIN (1939) reported that in the majority of cases examined by them, roentgen studies of the skull showed no evidence of raised intracranial pressure, and only one of their cases showed slight suture diastasis associated with heavy convolutional markings.

Of the seventeen verified cases included in this investigation the routine films of fifteen were considered normal, and those of only two showed slight changes suggestive of raised intracranial pressure.

2. Pneumography

The importance of LYSHOLM's work (1935, 1941, 1948) in establishing a ventriculographic syndrome for the diagnosis of pontine tumours has already been emphasized. The characteristic findings based upon conclusions, put together from his various works, may be summarized as follows:

1) Upward displacement of the posterior part of the third ventricle in the lateral view (Fig. 1).

2) Upward and backward displacement in a bow shape of the aqueduct and fourth ventricle as seen in the lateral view (Fig. 1).

3) No (or only very slight) deviation of the aqueduct and fourth ventricle from the midline in the postero-anterior film.

4) Internal hydrocephalus absent or only slight.

He emphasized that the absence of lateral deviation is an important point of differential diagnosis from cerebello-pontine angle tumours.

The only lesions mentioned by him which may give a similar picture are clivus meningioma and basilar impression. The former, he says, cannot be definitely differentiated by ventriculography, and one has to rely on the clinical aspects of the case. Basilar impression or platybasia, of course, may be diagnosed from the ordinary roentgenograms.

In all of LYSHOLM's eleven verified cases there was air in the aqueduct or the 4th ventricle, or in both, and sufficient to make localisation diagnosis; in all but one case a pons tumour was correctly diagnosed. The exception was a case diagnosed as a tumour of the cerebello-pontine angle on account, as he puts it, 'of the obliquity of the fourth ventricle which simulated a shift'. These findings are clearly important. If an almost pathognomonic appearance is demonstrated in ten out of eleven cases then the method is of the greatest diagnostic value. Ventriculography appears to have been the method of examination in all cases.

Unfortunately other work on the same subject is remarkably scanty and, with one or two honourable exceptions, of little value.

JOHNSON and LIST (1938) published reports of two cases of pontine tumours which were examined by ventriculography. They did not state whether pathologic verification was obtained. They affirmed that ventriculography adds little information when these tumours are small; if however, an intrapontine tumour reaches sufficient size, it will produce more or less marked hydrocephalus and certain characteristic local deformities. The aqueduct or fourth ventricle are displaced upwards or posteriorly, the distance between them and the clivus being increased.

Their first case is described as showing such an upward displacement, and the air in a dilated aqueduct as outlining the nodular superior margin of the tumour. The second case is claimed to show a laterally placed pontine tumour as proved by lateral displacement of the aqueduct and fourth ventricle. The films (or possibly the reproductions) seem capable of other interpretations whilst the technique is clearly open to criticism.

GARDNER and SHANNON (1944) give a much more satisfactory description of two cases of verified pontine glioma in children. Both their cases were examined by encephalography and the diagnosis established. This method was used because there was no evidence of raised intracranial pressure. The clinical diagnosis in both cases was encephalomyelitis or pontine neoplasm. Backward displacement of the aqueduct and fourth ventricle was well shown. In the first case the pontine cistern was filled with air and a direct measurement of the swollen pons rendered possible. Its diameter was said to be 3.6 cm, though the focus-film distance was not stated. (DAVIDOFF and DYKE (1939) give the normal diameter of the pons as measured on their encephalographic films as 2.5 to 3 cm.) No filling of the pontine cistern was shown in the second case and it was assumed that it was probably obliterated. However, as it is frequently

not visualized in normal cases unless special attempts are made to show it, the assumption was not necessarily correct, and the measurement of the pons diameter as the distance from the clivus to the aqueduct seems unwarranted, though possibly correct.

The other features of the cases to which attention is drawn were the convex floor of the fourth ventricle (in contrast to the normal flatness or slight concavity), the upward bulging of the floor of the third ventricle posteriorly, and the flattening out of the curve of the aqueduct. Both these cases showed a moderate hydrocephalus.

A previous report of an encephalography in a case of probable pontine tumour was made by ROBERTSON (1941) who recorded three similar cases in 1946.

Apart from the papers described above, only a few isolated or coincidental descriptions of contrast studies in cases of pontine tumours have been traced in the literature.

PILCHER and WILSON (1934) mentioned three cases, but do not appear to have gone further than a localisation diagnosis of 'posterior fossa tumour'.

ALPERS and WATTS (1935) in a clinical study of mesencephalic glioma stated that in seven cases involving the tegmentum, there was a filling defect in the posterior part of the third ventricle in four, and that in all the cases the aqueduct and fourth ventricle were displaced backwards, or not visualized. The aqueduct was only filled in three cases, presumably because the technique was not adequate.

MCCONNELL and CHILDE (1937) mentioned one case of pontine glioma in which no air filling of the aqueduct or fourth ventricle was obtained.

GARILLO (1937) described a case examined with lipiodol which showed typical and diagnostic backward displacement of the aqueduct and fourth ventricle.

TWINING (1939) stated that he had no personal experience of pontine tumours but gave schematic drawings showing the deformities of the third ventricle and aqueduct which might be expected with an interpeduncular and upper pons tumour, as well as with a pontine tumour. These show pushing upwards of the floor of the third ventricle, and displacement backwards of the aqueduct respectively, as in Fig. 1.

Many otherwise excellent and comprehensive reviews of pontine tumours including that of GUILLAIN, BERTRAIN, and GRUNER (1945) either make no mention of pneumography or merely record that ventriculography was performed without attempting to elaborate the point. It is clear that the potentialities of pneumography and LYSHOLM's work are not yet generally known among neurologists and neurosurgeons concerned with these cases.

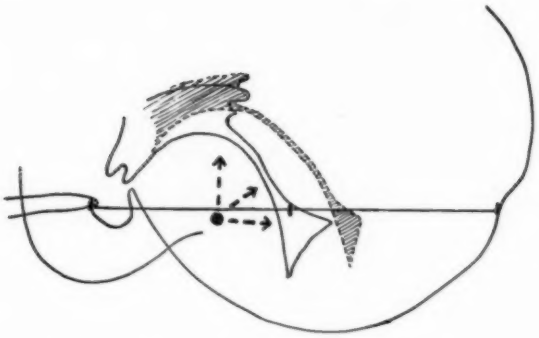


Fig. 1. To illustrate the displacement of the aqueduct, third, and fourth ventricles produced by a pontine tumour.

In many cases recorded, the technique used seems to have been quite inadequate. In some, the authors appeared to be content with a radiologic diagnosis of 'posterior fossa tumour' — apparently unaware that the aqueduct and fourth ventricle can and should be demonstrated in nearly all cases of posterior fossa tumour.

Technique. As with LYSHOLM's cases, air ventriculography appears to have been the method of examination used in most cases recorded. In a previous communication in 1950, the author reviewed the technique of demonstrating the aqueduct and fourth ventricle, and the methods of assessing their normality. The techniques used are:

1. Air ventriculography.
2. Positive contrast ventriculography.
3. Air encephalography (by the lumbar or cisternal route).

All three of these methods have been used in the present series of cases. The method used has depended on changing views on the value of different methods and their dangers and indications. The writer's present viewpoint is that air encephalography will be the method of choice in most cases and will usually give the most satisfactory results. However, air ventriculography should also afford good diagnostic results in most cases, and positive contrast will usually resolve the problem of the difficult case in which air ventriculography remains equivocal.

Assessment. As regards assessment of the aqueduct and fourth ventricle once demonstrated, this, as is well known, may be a matter of considerable difficulty, and at this point the main principles used by the writer may be briefly explained. Most cases can be rapidly checked by reference to:

(a) Twining's line — defined as a line joining the tuberculum sellae to the internal occipital protuberance. The midpoint lies in the fourth ventricle (Fig. 2).

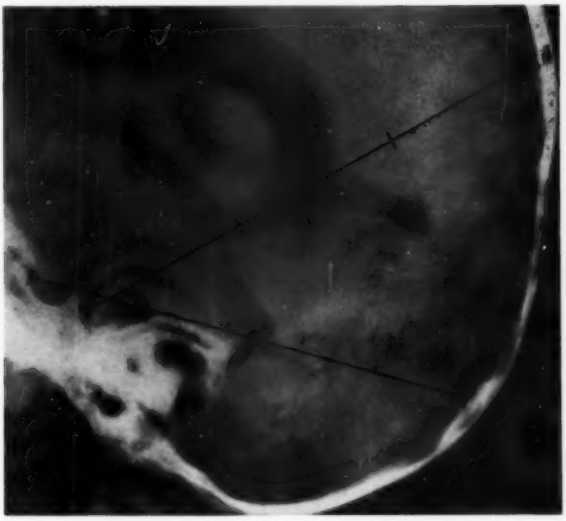


Fig. 2. Normal encephalogram in a child showing the relationship of the aqueduct and fourth ventricle to Lysholm's point and Twining's point respectively.

(b) Lysholm's line — defined as a line from the dorsum sellae through the aqueduct to the inner surface of the skull vault. The aqueduct lies below the junction of the middle and lower thirds (Fig. 2).

Twining's line has proved the more sensitive and accurate in detecting abnormality in cases of pontine tumours. In an occasional difficult case more precise measurement must be undertaken (SUTTON 1950). Those used and for which an attempt was made to establish a range of normal values are as follows:

1. The distance from the dorsum sellae to the aqueduct.
2. The distance from the dorsum sellae to the floor of the fourth ventricle.
3. The length of the aqueduct.
4. The width of the aqueduct.
5. The height of the fourth ventricle from the floor to the fastigium.
6. The distance from the fastigium to the mouth of the aqueduct.
7. The ventricular angle — defined as the angle between the floor of the third ventricle and a line joining the mouth of the aqueduct to the floor of the fourth ventricle.

Analysis of cases. The cases were devided into two groups, one consisting of children up to the age of 16, and another of adults but including adolescents of 16 years and over, this age being taken as an arbitrary dividing line.

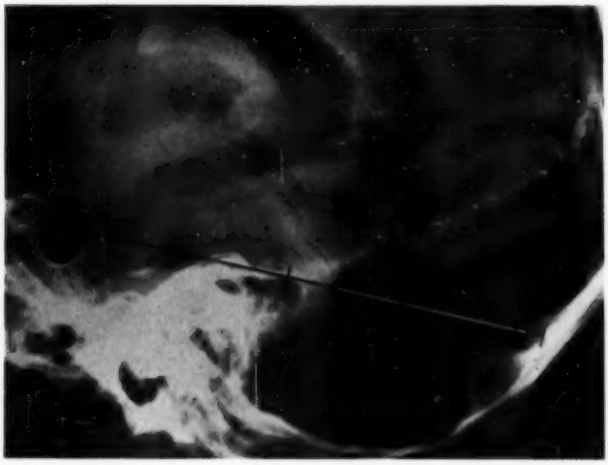


Fig. 3. Ventriculogram. Classical appearances of a pontine tumour.

Many cases showed significant variations and irregularities compared with the classical picture described by LYSHOLM. A definite diagnosis was however still possible. There was also a well-marked difference in the findings in children and in adults; they appear to form separate groups with different characteristics.

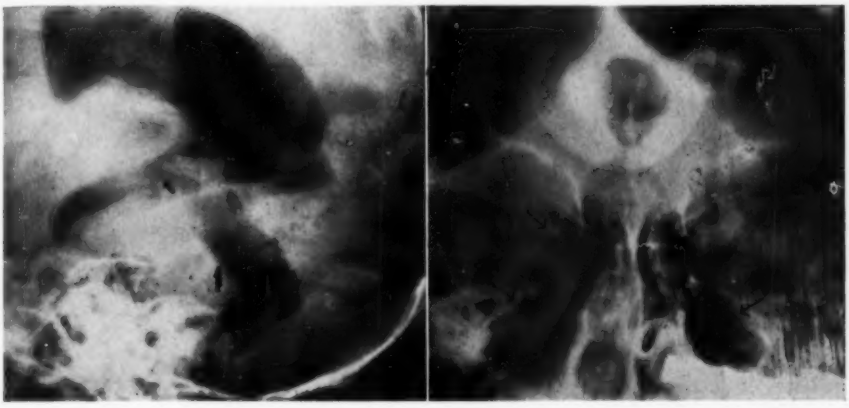
The children show a picture which in general conforms to the classical appearances described by LYSHOLM, with backward displacement of a central aqueduct, or fourth ventricle, as its main feature (Fig. 3).

The adults (including adolescents) showed on the whole less marked pneumographic changes, and as a group are much less typical. In some cases diagnostic changes are only detectable by the most careful analysis and measurement, and would probably have been missed without the aid of positive contrast ventriculography or of encephalography.

Eight children all showed a backward displacement of the fourth ventricle. The distance of its floor behind Twining's point varied from 4 to 24 millimeters, and the floor was usually convex in contrast to the normal flatness or slight concavity (Fig. 3). This in itself was a diagnostic finding. The relationship of the aqueduct to the Lysholm point was less constantly altered — in three of these eight cases it was normal, a rather surprising finding.

As regards hydrocephalus, this was absent in three of the cases and slight or moderate in the others, which accords with the picture presented by LYSHOLM.

There were however, some coincidental unusual features among these cases of types not previously recorded, and these will be briefly described.



a. b.

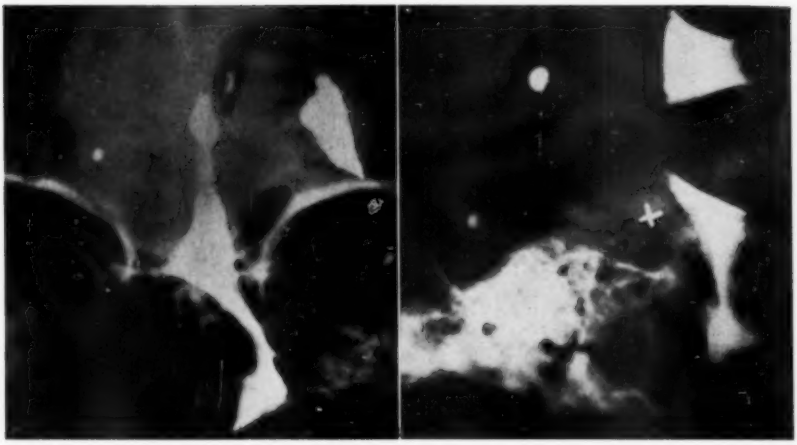
Fig. 4 (a, b). Ventriculogram. Enormous dilatation of a central fourth ventricle, which is clearly displaced backwards in relation to Twining's point (→).

Irregular dilatation of the aqueduct was present in one case, its maximum diameter being 7 mm against the normal 2 mm. It was also appreciably dilated in two other cases. This is in contrast to the more usual picture where the aqueduct appears narrowed or compressed (Fig. 3).

In one case, an unusually large dilatation of the fourth ventricle relative to the moderate hydrocephalus of the rest of the ventricular system was present. Nevertheless, as already stated, the picture remained diagnostic, because the floor of the fourth ventricle was clearly displaced backwards.

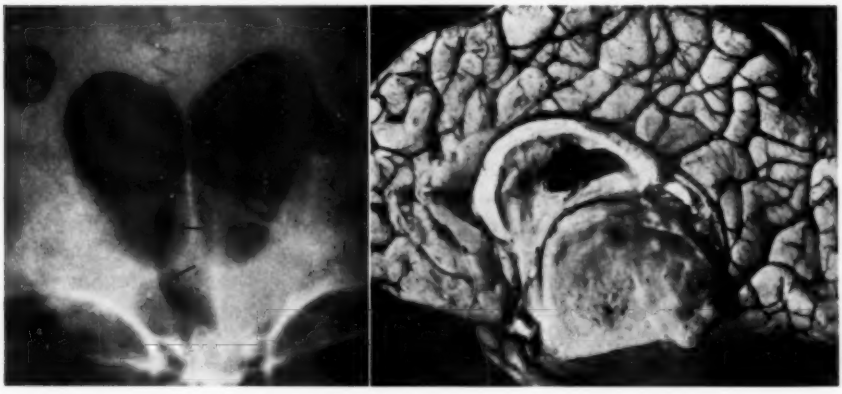
One case showed an appearance suggesting that the tumour was bulging into the fourth ventricle from below, this time mainly on the left side. This was beautifully confirmed by myodil ventriculography carried out some time later, which clearly demonstrated a rounded tumour mass bulging into the left half of the fourth ventricle. This unusual appearance led to some doubt as to whether the case really was a pontine tumour, to be dispelled by the diagnostic appearances in the lateral view (Fig. 5 a, b).

One case was an illustration of that type of tumour which extends along the cerebrospinal axis, and is not confined to the brainstem proper (Fig. 6 a). Similar cases are reported in the literature (GUILLAIN et al., 1945) and the writer has recently seen another such case in a girl of eleven. The name 'pontine tumour' is really a misnomer and 'brainstem tumour' is the more accurate term. The tumour may involve the medulla and the



a. b.

Fig. 5 (a, b). Myodil ventriculogram showing an unusual filling defect in the fourth ventricle, which is displaced backwards in relation to Twining's point (+).



a. b.

Fig. 6. a) Ventriculogram. Large thalamic tumour projecting into the third ventricle. b) Autopsy specimen. Tumour extending up from the brainstem into the thalamus.

pons, the midbrain as well as the pons, or all three elements of the brainstem. Again, as in this case, it may extend up into the thalamus, down into the spine, or back through the peduncles to the cerebellum.

In the ventriculogram the thalamic tumour was so obvious and the patient's condition so poor that the examination was not prolonged to

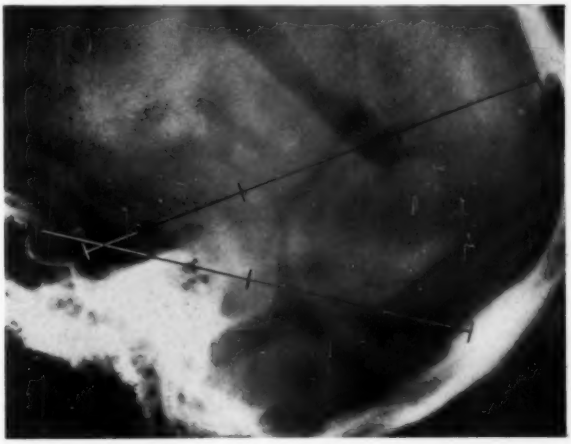


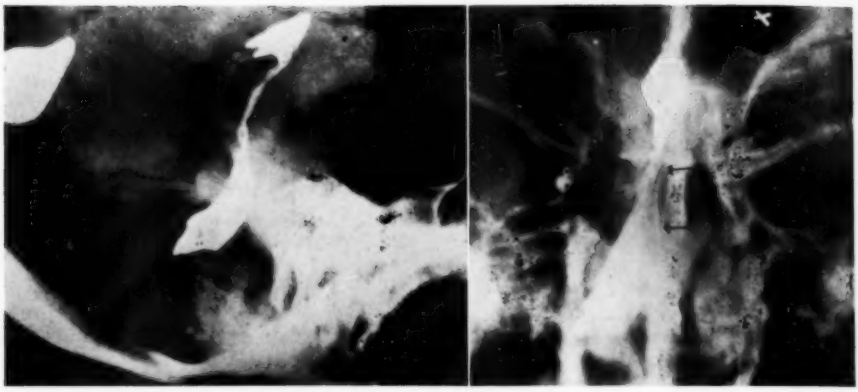
Fig. 7. Classical changes of pontine tumour in an adult.

demonstrate the aqueduct and fourth ventricle. The clinical findings of defects of conjugate ocular movements, a left facial palsy, left trapezius weakness, and cerebellar and pyramidal signs, made it certain that this was a more extensive lesion, primarily in the brainstem; the clinical diagnosis had been pontine tumour.

Once the presence of a large space-occupying neoplasm was confirmed, further manipulation and investigation of the child seemed unjustified. No doubt, judging from the autopsy findings (Fig. 6 b), persistence with the pneumographic examination, or myodil ventriculography, would have shown typical displacement of the aqueduct or fourth ventricle.

In the adults and adolescents few of the eight verified cases are immediately recognizable as conforming to the classical picture. One case is, however, an example of such changes (Fig. 7). In contrast, another case was mistaken for a cerebello-pontine angle tumour because the aqueduct and fourth ventricle were considered to be displaced laterally. The autopsy finding of symmetric broadening of the pons suggests roentgenologic misinterpretation. The films were certainly not of good diagnostic quality. Myodil might have given a more satisfactory answer in this case, as it did in others. It is interesting that LYSHOLM's one misdiagnosed case was of this nature.

One case was regarded as normal at the time of examination and superficially could pass as such. Measurements show the necessity for more careful examination of this type of case for they demonstrate minimal but diagnostic changes viz., the clivus—aqueduct distance was 4.1 cm (maximal normal length in the controls was 4 cm) and, more important,



a. b.

Fig. 8. Myodil ventriculogram, a) lateral view normal appearance, b) A. p. slight deviation of the aqueduct.

Twining's point was definitely anterior to the fourth ventricle. Another case similarly showed minimal changes which were only demonstrable after the use of myodil. In the lateral view the appearance could pass for normal and both Twining's point and Lysholm's point were in normal position (Fig. 8 a). Careful measurements, however, showed two abnormalities, (1) the ventricular angle was 75° (against not less than 85°), (2) the distance from the fastigium to the mouth of the aqueduct was 4.9 cm which is about the outer limit of normal. The antero-posterior myodil films of this case also showed another abnormality in that there was a slight lateral deviation of the aqueduct (Fig. 8 b). This type of local deviation of the aqueduct with little or no displacement of the fourth ventricle is very suggestive of a brainstem tumour.

Such a deviation was also shown by myodil in a case in which the fourth ventricle was also deviated. The lateral films, however, were diagnostic, although the possibility of a cerebello-pontine angle tumour had to be considered.

Another case showed minimal changes and both Twining's point and Lysholm's point were normal in position. Even on careful analysis and measurement only one definitely abnormal finding was recorded. The ventricular angle was 70° (Fig. 9).

We may conclude that cases in adults in this series show a much less typical picture than those in children, and that in many cases positive radiologic evidence of the lesion could only be obtained by a painstaking examination and a careful analysis of the pneumograms.

Fig. 9. Ventriculogram tracing showing ventricular angle of 70°.

It is equally clear however, that although the classical picture described by LYSHOLM is not seen as frequently as we would like, the diagnosis of pontine tumour should nevertheless be possible in all but a very exceptional case.

3. Vertebral Angiography

Vertebral angiography was only performed in one case of this series of verified pontine tumours (Case 16), and the appearances were considered to be within normal limits. This accords with the findings of RADNER (1950). However, although angiography gives no positive useful information it may prove valuable in a negative sense or in differential diagnosis. Thus it will differentiate between a pontine or a prepontine expanding lesion, a radiologic diagnosis which was formerly considered impossible.

Differential Diagnosis

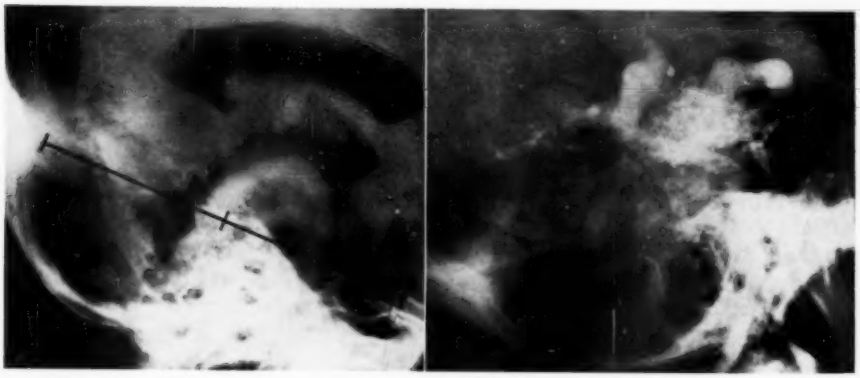
LYSHOLM mentioned two conditions as being of radiologic importance, *i. e.* clivus meningioma and basilar impression. The writer would greatly extend this short list. Among extracerebral conditions should be included: cerebello-pontine angle tumours, basilar aneurysms, chordomata, clivus meningiomata and angiomatous malformations. Among intracerebral lesions, tuberculomata, degenerative lesions, 4th ventricle tumours, angiomatous malformations and other vascular lesions must be considered.

Fig. 10 shows a vertebral angiogram in a case which had been regarded clinically as a probable pontine tumour. The backward displacement of the vertebral artery is clearly due, however, to an extracerebral tumour. It should be noted that in this case there was calcification behind the

Fig. 10. Vertebral angiogram. Basilar artery displaced back in an are by a prepontine tumour.

clivus; this in itself excluded the diagnosis of pontine tumour. Such calcification may occur in a meningioma, or in a chordoma; this proved to be the latter.

Fig. 11 a shows air studies in a case which had been regarded clinically for many years as a pontine tumour. The pneumographic appearances were in fact consistent with such a diagnosis. The unusually long history



a. b.

Fig. 11. a) Air encephalogram. Appearance similar to that of a pontine tumour. Note, however, the unusual irregularity of the posterior part of the third ventricle and of the aqueduct. b) Vertebral angiogram in the same case. Angiomatous malformation.

and some atypical features, *e. g.* the deformity of the back end of the third ventricle, led one to consider whether this might not be a more benign lesion, and the possibility of an angioma was suggested. Vertebral angiography was performed and proved this diagnosis to be correct (Fig. 11 b).

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This paper is based on sections of a thesis presented for the degree of doctorate at Manchester University. It could not have been undertaken without the assistance of Mr. WYLIE MCKISSOCK in permitting access to his excellent records, and the support and encouragement of Dr. HUGH DAVIES and Dr. JAMES BULL.

SUMMARY

An analysis of seventeen verified cases of pontine glioma is presented. Many of the cases however, showed atypical features, adults on the whole, showing changes less typical than children. Marked hydrocephalus may occur but is uncommon. Vertebral angiography is of no diagnostic value in pontine tumours but may be useful in the differential diagnosis.

ZUSAMMENFASSUNG

17 verifiierte Fälle mit pontinen Gliomen werden analysiert. Viele Fälle zeigten atypische Züge, Erwachsene im Allgemeinen mehr als Kinder. Ausgesprochener Hydrozephalus kann auftreten, ist jedoch ungewöhnlich. Die Vertebralisangiographie hat bei den pontinen Tumoren keinen diagnostischen Wert; sie kann jedoch für die Differentialdiagnose von Nutzen sein.

RÉSUMÉ

L'auteur présente une étude analytique de dix-sept cas vérifiés de gliome protubérantiel. Beaucoup de ces cas présentaient des signes atypiques, les adultes présentant dans l'ensemble des signes moins typiques que les enfants. Il peut exister une hydrocéphalie marquée, mais elle est peu fréquente. L'angiographie vertébrale n'a aucune valeur diagnostique dans les tumeurs protubérantielles mais peut servir au diagnostic différentiel.

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FROM THE DEPARTMENTS OF RADIOLOGY, SAHLGRENSKA SJUKHUSET, GOTHENBURG, SWEDEN, AND THE RADCLIFFE INFIRMARY, OXFORD, ENGLAND

SOME ASPECTS OF THE RADIOLOGIC DIAGNOSIS OF POSTERIOR FOSSA AND SUPRA-SELLAR TUMOURS

by

Ingmar Wickbom and *Philip Sheldon*

Until some years ago, ventriculography was the method of choice in the radiologic examination of the posterior fossa. In many centres this is still so. Encephalography was considered to be less reliable than ventriculography and to be contra-indicated if the intracranial pressure was raised. This belief was justified as long as encephalography was performed by the method in which the radiologic examination started only when the injected air was in the lateral ventricles, but by the introduction of the methods described by ROBERTSON (1941) and LINDGREN (1949) the chances of diagnosing and localising a posterior fossa tumour became greatly increased.

We use the technique described by LINDGREN at the last Symposium Neuroradiologicum (published in Acta Radiologica). It therefore seems unnecessary to describe the technique in detail. We shall only point out that by taking films during the phase of injection of the air with the patient in the sitting position, the pathway of the air can be judged, and by altering the position of the head, the air can be directed into ventricles or cisterns as required. We always inject more air than the amount of cerebrospinal fluid which escapes, in order to keep the pressure as constant as possible. In cases with raised pressure, almost no fluid is withdrawn and a single fine needle is used to prevent any later leakage of cerebrospinal fluid. This technique diminishes the risks of causing downward herniation of the cerebellum or the midbrain, and enables the appearances of the fourth ventricle, aqueduct and the basal cisterns to be studied.

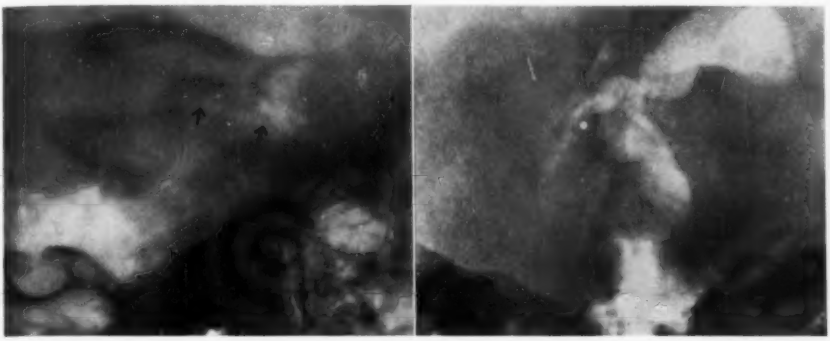
The development of a satisfactory technique for vertebral angiography has also increased the possibilities of studying posterior fossa lesions

radiologically. Several methods have been described in the last few years — the catheter method (RADNER 1951), percutaneous puncture in different places and indirect injection from the subclavian or carotid artery. We use the percutaneous method (LINDGREN 1950) and consider that with practice this method seldom fails. It is true that vertebral angiography does not give as much information about posterior fossa tumours as carotid angiography provides about tumours of the cerebral hemispheres, but in some cases, especially those with very vascular lesions, valuable information may be obtained from vertebral angiograms.

The development of the technique of encephalography and vertebral angiography means, in our opinion, that the radiologic approach to the diagnosis of posterior fossa tumours should be different from that used a few years ago when ventriculography was almost invariably used. In as many cases as possible, encephalography often supplemented by vertebral angiography should be substituted for ventriculography. It may not always be possible to fill the ventricles by encephalography, usually owing to obstruction of the foramen of Magendie, but even in such cases, accurate localisation of the tumour may often be made from the appearances of the cisterns, or of the vascular changes if vertebral angiography is carried out. It will probably be found that encephalography will not fill the ventricles if there is obvious evidence of a cerebellar tumour with papilloedema, although even in such cases ventricular filling may be obtained if decompression has previously been carried out.

Ventriculography is a more serious procedure than encephalography partly on account of the manipulation usually needed to outline the aqueduct and fourth ventricle, and even if performed by an experienced neurosurgeon, there is some small risk of causing a haemorrhage into the brain tissue. In a follow-up examination B. FALK found calcifications in the site of track of the puncture needle after previous ventriculography in 27 out of 203 cases. This shows that brain damage caused by the puncture is fairly common even if fresh symptoms which could unequivocally only be caused by them were not found. In our opinion the risks of causing a herniation of the brain are no greater in encephalography than in ventriculography, if the examination is competently and carefully carried out. As a safeguard the patient should be closely watched afterwards, and arrangements made to operate should his condition deteriorate.

In the first four cases to be presented, the clinical symptoms favoured a tumour in the cerebello-pontine angle or its vicinity, and the appearances of the fourth ventricle, aqueduct, and the basal cisterns made it possible to make an accurate localisation of the tumour from the encephalograms.



a. b.

Fig. 1, Case 1. Cholesteatoma antero-lateral to the brain stem. Encephalogram. (a) Lateral view erect. The aqueduct is displaced backwards and upwards, and the posterior part of the third ventricle is displaced upwards. (b) P. A. view erect. Fourth ventricle is displaced to the left. Right lower ambient cistern is displaced medially. Right lateral pontine recess does not fill. Left lateral pontine recess and right ambient cistern fill normally.

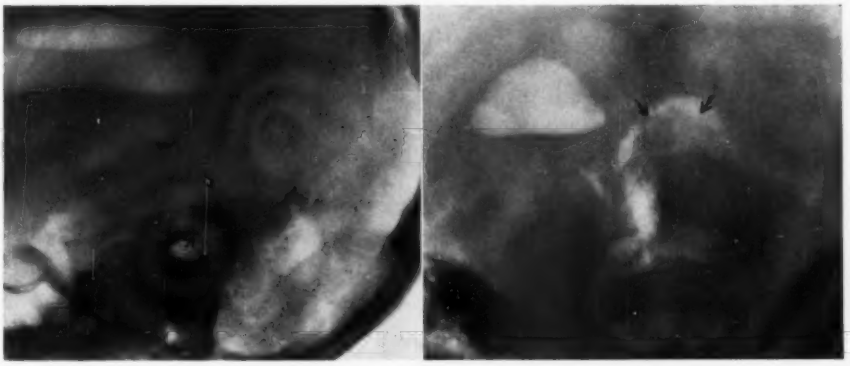


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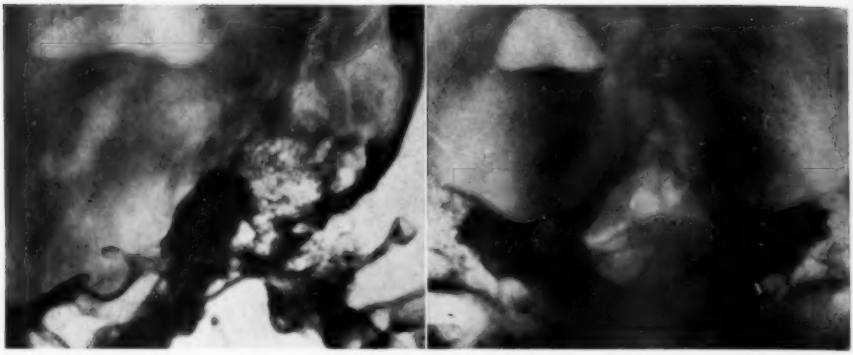
Fig. 2, Case 2. Cholesteatoma in fourth ventricle. Encephalogram. (a) P. A. view erect. (b) Lateral view erect. A lobulated tumour is shown in an enormously dilated fourth ventricle.

Case 1. V. V., female, aged 37 (R. I. 130227/50). History of occipital headache for eight years. Gradual onset of symptoms related to the right fifth, seventh and eighth nerves. Cerebro-spinal fluid pressure and protein content were normal.

Encephalography showed marked upward and backward displacement of the aqueduct and upward displacement of the posterior part of the third ventricle (Fig. 1 a). The fourth ventricle was compressed from in front and displaced a little to the left.



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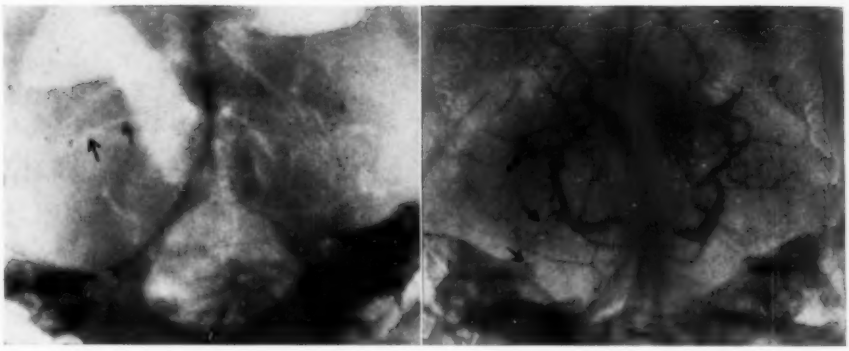


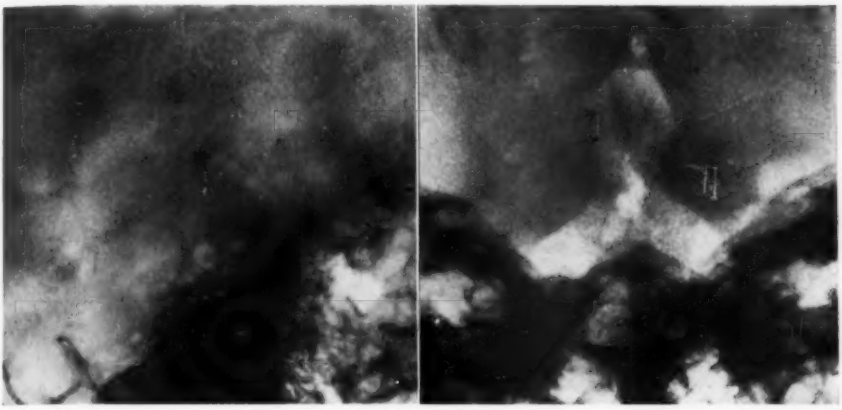
c. d.

Fig. 3, Case 3. Meningeoma in the right pontine angle. Encephalogram. (a) Lateral view erect. (b) P. A. view erect. The 4th ventricle is displaced to the left. (c) P. A. view erect after filling of the cisterns. The right ambient cistern is displaced upwards surrounding the tumour. (d) Vertebral angiogram. The right middle cerebellar artery is displaced in an arch directed upwards and laterally.

The lower part of the right ambient cistern was encroached on from its lateral side, and displaced medially and the right lateral pontine cistern did not fill. The left lateral pontine and ambient cisterns looked normal (Fig. 1 b).

The ventricular changes could have been due to an asymmetric pontine tumour, but in such a case, the right pontine recess and right ambient cisterns would have looked normal. The appearances of the cisterns in fact showed that the tumour lay outside the pons.

At operation (Mr. PENNYBACKER) a cholesteatoma was found lying anterior and to the right of the brain stem.



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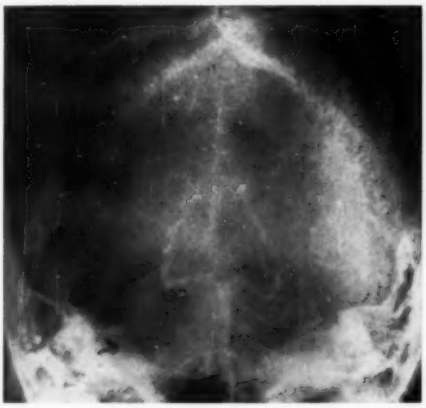


c.

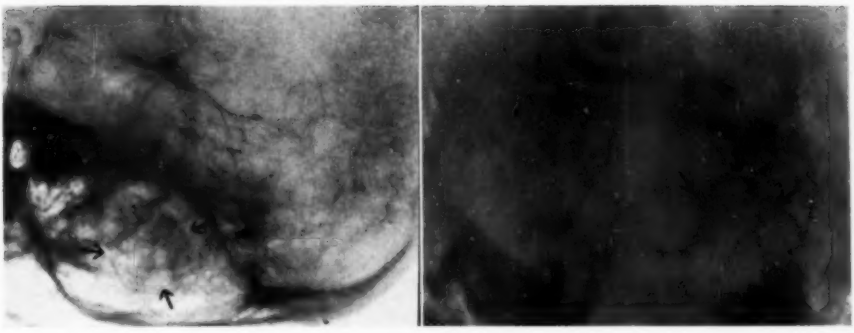
Fig. 4, Case 4. Glioma in the right part of the pons (autopsy). Encephalogram: (a) Erect lateral view. (b) P. A. view erect. The aqueduct is elevated. There is a slight indentation in the 4th ventricle from the right but no definite shift. Vertebral angiogram (c). The right middle cerebellar artery lies in a marked arch passing close to the meatus.

Case 2. E. C., female, aged 39 (R. I. 133140/50). History of increasing unsteadiness of left limbs for last five years, deafness in left ear, twitching in the left side of the face, and left occipital headache.

No papilloedema was found. Signs relating to the left fifth, seventh and eighth nerves and left cerebellum were present. Cerebro-spinal fluid pressure was normal, and the protein content was 95 mgm/100 ml. Preliminary radiographs of the skull revealed no changes. An encephalogram showed a large lobulated mass lying in an enormously dilated fourth ventricle. The lateral pontine recesses filled normally with air (Fig. 2 a and b).

At operation (Mr. PENNYBACKER) a large cholesteatoma was removed.

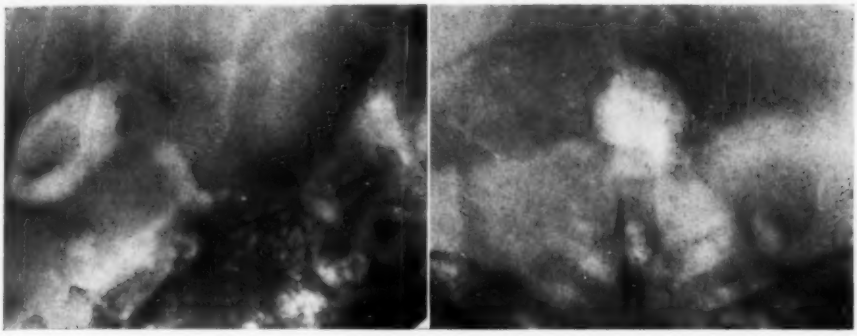
a. b.



c. d.

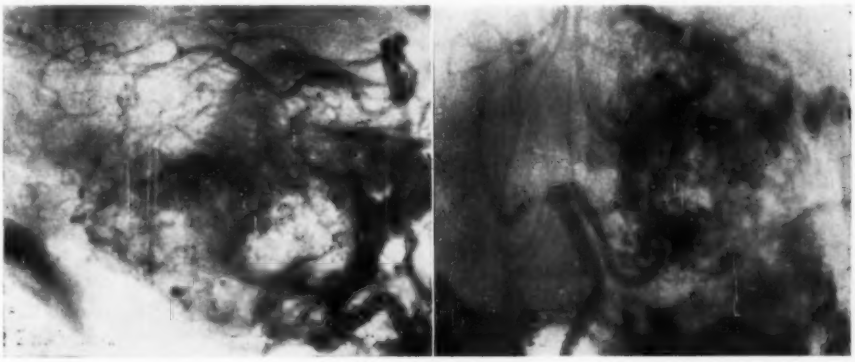
Fig. 5, Case 5. Metastasis in the left cerebellar hemisphere (from a lung carcinoma). (Autopsy.) Encephalogram: (a) Erect lateral view. No filling of the ventricular system. The tonsils are depressed below the foramen magnum. (Arrows.) Vertebral angiogram: (b) Arteriogram. (c and d) Phlebogram. Tumour circulation best seen in the A. P. view. (Arrows.)

Case 3. Female, aged 52, presenting a history of increasing deafness in right ear for 5—10 years and unsteady gait for the last few years. Caloric response was absent and corneal reflex diminished on the right side. On encephalography there was a marked displacement upwards and to the left of the aqueduct and the fourth ventricle (fig. 3 a and b). The ambient cistern was displaced upwards surrounding a large tumour in the right pontine angle (fig. 3 c). On vertebral angiography the middle cerebellar artery on the right side was seen to lie in a marked arch directed upwards. The artery could be seen down to the internal meatus but did not pass it. The appearance of the cisterns and to some extent the vascular displacement indicated an extracerebral tumour. At operation (Dr. SJÖQVIST) a large meningeoma was removed.



a. b.

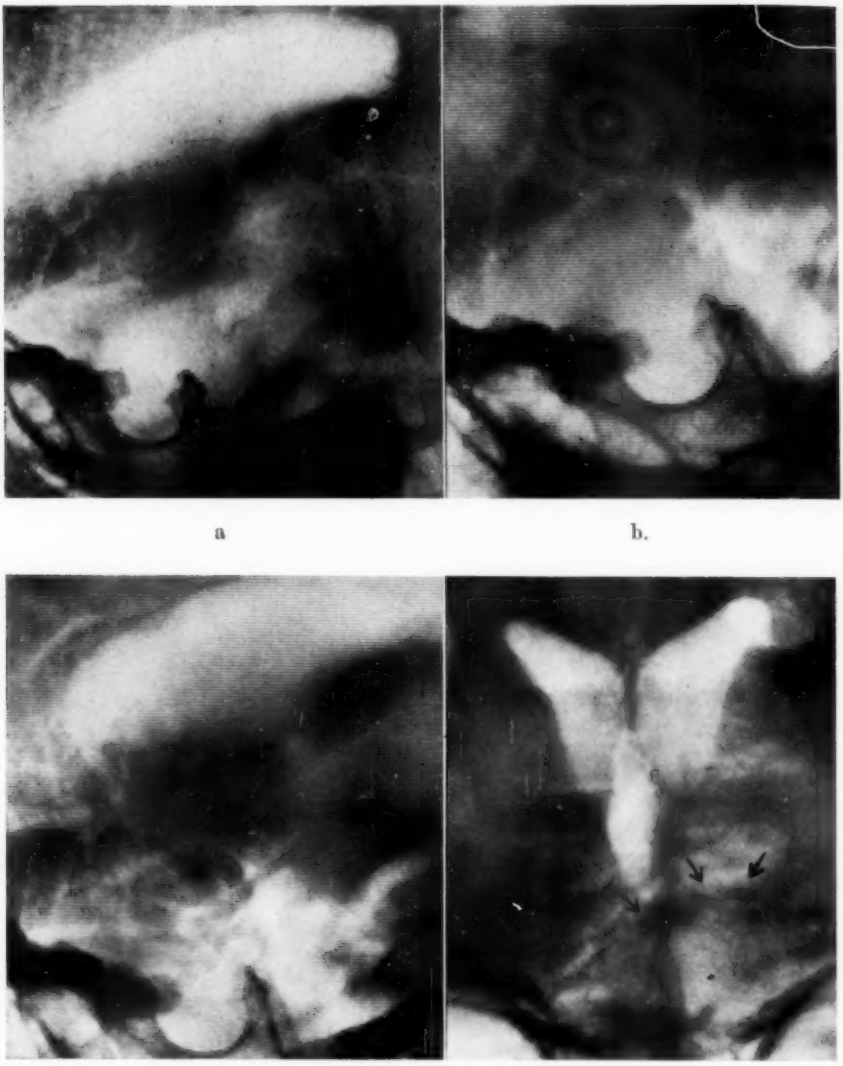
Fig. 6, Case 6. Recurrent cerebellar haemangioblastoma. Encephalogram showing that air can pass into the ventricular system after a suboccipital decompression has been performed. (a) Lateral view erect. (b) P. A. view erect. The aqueduct is sharply kinked forward and the fourth ventricle is displaced to the left.



a. b.

Fig. 7, Case 7. Left cerebellar haemangioblastoma. (a) and (b) Vertebral angiogram. There is a large circumscribed mass of blood vessels in the left cerebellar lobe. The left superior cerebellar artery is considerably enlarged.

Case 4. Male, aged 20, had, for one year, observed weakness and ataxy of the left arm and later also of the left leg. He complained of tiredness and vertigo. There was also paresis of the left side of the face and diplopia but no deafness. On encephalography (fig. 4 a and b) there was a marked elevation of the aqueduct and a slight indentation of the fourth ventricle from the right. The right cerebello-pontine recess did not fill, the left recess filling normally. In a vertebral angiogram (fig. 4 c) the right middle cerebellar



a b.

c. d.

Fig. 8, case 8. Small meningeoma arising from the tuberculum sellae. Encephalogram. (a) Ventriculogram one year before last examination. The anterior recesses of the third ventricle and the anterior horns are normal. (b) Erect lateral view. (c) A. P. view in supine by air in the chiasmatic and adjoining cisterns. The anterior horns and the third ventricle are normal.

Fig. 9, Case 9. Right olfactory groove meningeoma. (a) A. P. view of right carotid angiogram with contralateral carotid compression. The first part of the right anterior cerebral artery is narrowed and elevated. Small tightly stretched vessels can be seen running over the surface of the tumour which crosses the midline.

artery was seen to lie in a stretched arch directed upwards and laterally passing close to the internal meatus. From the appearances of the encephalogram it could not be definitely decided whether the tumour was an asymmetric pontine tumour or a pontine angle tumour situated unusually basally. The latter could however be excluded from the appearance of the artery passing close to the meatus. Some recovery followed roentgen treatment but after half a year the symptoms recurred and the patient died. At autopsy a glioma was found in the right part of the pons.

Case 5. Male, aged 64. The clinical findings were indefinite. General deterioration and personality changes were present, and a subdural haematoma was suspected.

A carotid angiogram showed no evidence of this but there were signs of slight hydrocephalus. On encephalography, air in the cisterna magna showed depression of the tonsils. (Fig. 5 a.) No ventricular filling was obtained. No definite localisation of a tumour could be made from the appearance of the air in the basal cisterns. A vertebral angiogram showed a vascular tumour in the left cerebellar lobe (Fig. 5 b—d). This proved to be a metastatic deposit.

This case also shows that it is usually not possible for air to pass into the ventricles when a cerebellar tumour is present. In our experience ventricular filling occurs only if a suboccipital decompression has been performed, as the next case will show.

Case 6. O. N. male, aged 44 (R. I. 133659/38) had a cerebellar haemangioblastoma removed by the late Sir HUGH CAIRNS in 1938. Symptoms recurred in 1950 and were at first attributed to hypertension since there was no evidence of raised intracranial pressure. Encephalography was carried out. This showed the aqueduct and third ventricle to be moderately dilated. The aqueduct was sharply kinked forward just below its origin (Fig. 6 a). The lower part of the aqueduct and the fourth ventricle were displaced to the left (Fig. 6 b). At further operation a large very vascular haemangioblastoma was found in the right cerebellar hemisphere.

The following case is another example of the value of vertebral angiography in the diagnosis of vascular lesions in the posterior fossa and in following the progress of a tumour or its response to treatment.

Case 7. H. B., male, aged 61 (R. I. 107552/49). On first admission in 1949 a posterior fossa exploration showed evidence of a cerebellar haemangioblastoma, but no further action was taken at that time. Subsequent vertebral angiography showed a large and very vascular lesion in the left cerebellar lobe. After a course of radiotherapy which had little clinical effect, the vertebral angiography was repeated, and the appearances were unchanged (Fig. 7 a & b). The lesion, which was subsequently shown to be a solid haemangioblastoma was removed (Mr. PENNYBACKER).

In cases with supra-sellar and subfrontal tumours, if the tumour is small, the ventricular and angiographic systems may be normal and no lesion found unless encephalography is used.

Case 8. N. G., female, aged 38. (R. I. 91145/48). Small left olfactory groove meningeoma. Complained of failing vision in the right eye for one year and of headaches.

Two years before the last admission a ventriculogram (including te anterior recesses of the third ventricle) had been normal. Bilateral carotid angiograms were inconclusive, the right anterior cerebral artery not being filled with contrast material. The patient was readmitted because her symptoms and signs had become worse. Encephalography was performed. The air in the anterior basal cisterns outlined a small tumour above the inner end of the left lesser sphenoidal wing (Fig. 8 a—d). The third and lateral ventricles appeared normal.

On operation (Mr. PENNYBACKER) a small meningeoma arising from the posterior end of the left olfactory groove was removed.

In another patient (Case 9) with a similar tumour, no filling of the right anterior cerebral artery was obtained upon right carotid angiography until pressure was exerted on the opposite carotid artery. Both anterior cerebral arteries were then visualised (Fig. 9) and these, by their displacement, indicated a supra-sellar tumour. The horizontal portion of the right anterior cerebral artery was much narrowed, and a little elevated. In addition, tumour circulation was seen. Encephalography was also performed and showed a tumour outlined by air in the chiasmatic and adjoining cisterns. The third ventricle was normal, although the tumour crossed the midline. The floor of the anterior horn of the right lateral ventricle was a little elevated. At operation a meningeoma from the olfactory groove was removed.

Conclusions

The findings in these cases demonstrate that it is necessary to select the method of examination in each case. In most cases of cerebello-pontine angle and midbrain tumours, encephalography, by outlining the cisterns as well as the aqueduct and fourth ventricle, will make it possible to localise the lesion more accurately than by ventriculography. Vertebral angiography may also be of use especially where there is a vascular tumour of the cerebellum. In cases with avascular tumours of the cerebellum, ventriculography usually gives most information, although it may be that with further experience, examination of the cisterns and vessels in such cases may enable the diagnosis to be made with encephalography and vertebral angiography. While large supra-sellar and subfrontal tumours may be shown easily by means of ventriculography and carotid angiography, small tumours may escape recognition unless air encephalography and special angiographic projections are used.

Acknowledgments

The authors wish to thank Mr. J. B. PENNYBACKER for permission to report the cases from the Neurosurgical Department, Radcliffe Infirmary, Oxford, including those already reported by SHELDON, WICKBOM and PENNYBACKER (in press).

SUMMARY

The authors discuss the uses of air encephalography, ventriculography and angiography in the diagnosis of posterior fossa and supra-sellar tumours. Nine cases are briefly reported to illustrate the points mentioned. They consider that greater use should be made of air encephalography, and that it is not contra-indicated even in patients with some increase in intracranial pressure.

ZUSAMMENFASSUNG

Die Verf. diskutieren den Wert der Luftenzephalographie, der Ventrikulographie und der Angiographie für die Diagnose der Tumoren der hinteren Schädelgrube und der supraselläre Tumoren. 9 Fälle werden kurz beschrieben, um die erwähnten Gesichtspunkte zu illustrieren. Die Verf. sind der Meinung, dass die Luftenzephalographie in grösserem Ausmasse angewendet werden sollte und dass sie auch bei Patienten mit leichter Steigerung des intrakraniellen Druckes nicht kontraindiziert ist.

RÉSUMÉ

Les auteurs discutent l'emploi de l'encéphalographie gazeuse, de la ventriculographie et de l'angiographie pour le diagnostic des tumeurs de la fosse postérieure et de la région parasellaire. Neuf cas brièvement présentés illustrent les points mentionnés. Les auteurs pensent qu'on devrait utiliser plus largement l'encéphalographie et qu'elle n'est pas contre-indiquée, même chez les malades qui présentent un certain degré d'hypertension cranienne.

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VENTRICULOGRAPHY WITH SMALL AMOUNTS OF AIR

by

B. G. Ziedses des Plantes

Introduction

Ventriculography with small amounts of air was discussed during the Symposium in 1949. We described how it is possible to cause a small amount of air to enter the third an fourth ventricles and to spread into the basal cisternae and over the brain surface. The object of the present publication is to show that a similar procedure may be applied to distribute a small amount of air over both inferior horns so as to depict them simultaneously.

It may be permissible to introduce the subject by repeating a part of the former paper which was in French.

In expanding lesions we, in our clinic, consider ventriculography a rather dangerous procedure, especially if there exists an obstruction to the pathways of the cerebrospinal fluid. The risk may be reduced, firstly, by paying special attention to keeping the intracranial pressure at a constant level and, secondly, by introducing only small amounts of air.

In expanding lesions of the brain we generally prefer arteriography; but in changes which give rise to obstruction of the third ventricle, the aqueduct of Sylvius, the fourth ventricle, or the basal cisternae or in those on the brain surface, we often need ventriculography. It is just in such cases that ventriculography is a dangerous procedure if the quantities of air used are large.

The Backward Somersault

In the method to be described we proceed as follows (Fig. 1 in previous paper).

A small amount of air, *i. e.* 10 ml, is injected into the lateral ventricles, in the newborn through the fontanel, in adult patients through

Fig. 1. The result of the backward somersault in case of a tumour blocking the posterior part of the third ventricle. (Lateral view in prone position.)

burr-holes. Some of the air may possibly pass into the descending horn. In order to get all the air into the anterior horn, the patient is placed in an upright position, with the head bent a little forwards. Returning the patient to the supine position will cause all the air to enter the anterior horns. If the patient is turned over backwards, the anterior part of the third ventricle will first of all be filled with air. (The reader is referred to Fig. 1 in the author's previous paper in Acta radiol., Vol. 34, p. 400.)

Making the patient turn a complete backward somersault causes the air to spread into the posterior part of the third ventricle and, if the aqueduct of Sylvius is not obstructed, into the fourth ventricle. If there is no obstruction, the air will escape to the cisterna magna and occasionally to the spinal canal. It will be explained later, how in that case the examination should be continued. (As the figure shows, it is an easy matter to make a baby turn the desired somersault. Somewhat greater difficulties arise with an adult patient.) Fig. 2 in the above-mentioned publication of the author depicts the manner in which the desired turning of the head may be achieved. The patient lies on his back with the head hanging down and the roentgen table tilted. The patient is then turned into the prone position and simultaneously the head is turned in such a way that the sagittal plane remains vertical.

If the patient's condition does not allow of such extreme flexion of the head, the table may be tilted further. Fig. 1 shows the results in a case of medulloblastoma.

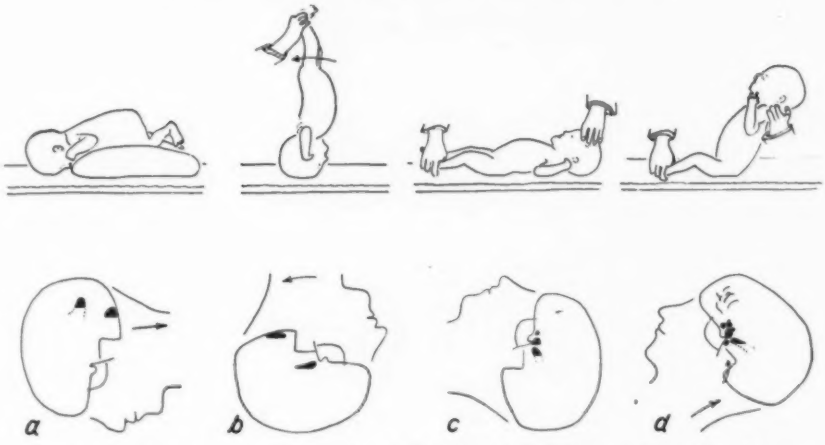


Fig. 2. Forward somersault to check whether the pathways from the cisterna magna to the surface of the cerebral hemispheres are free.

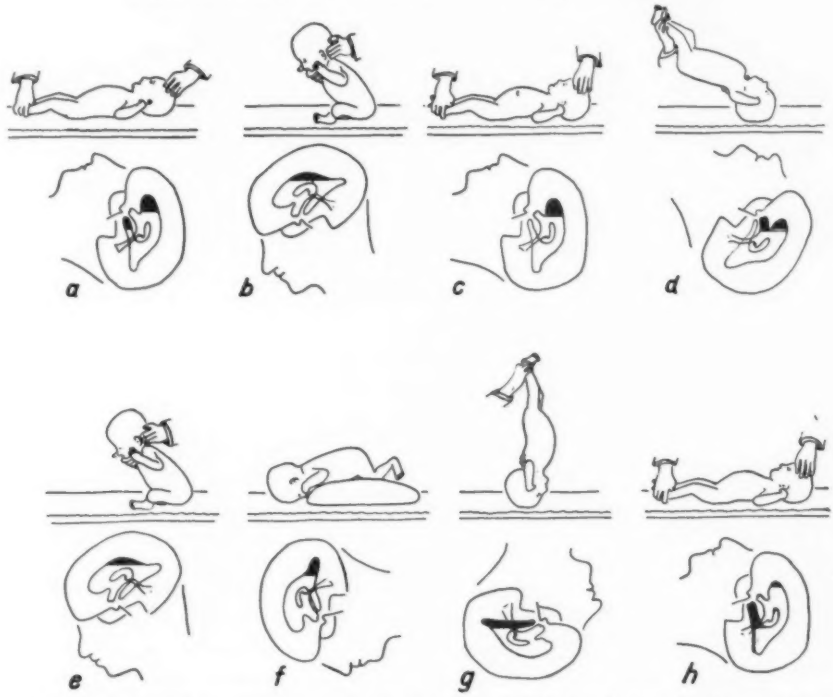
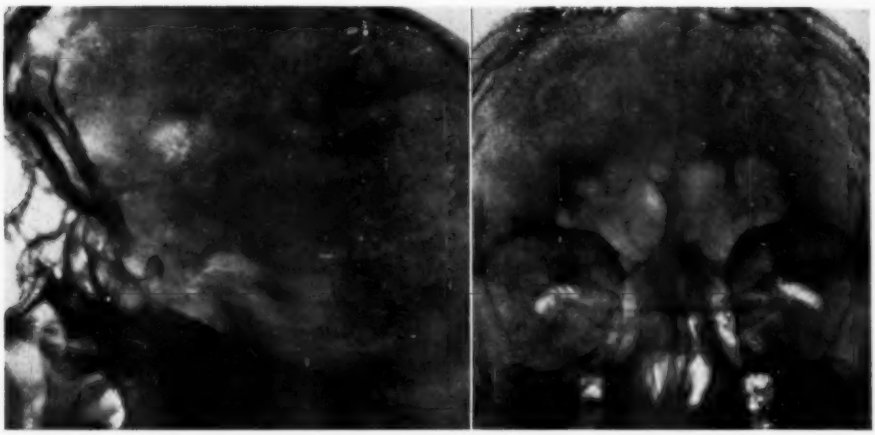


Fig. 3. Forward somersault in order to fill both inferior horns simultaneously.



a. b.

Fig. 4. Both inferior horns filled after forward somersault in a normal case. a. Lateral view; b. A. p. view.

It is also possible to obtain a representation of the fourth ventricle in cases in which there is no obstruction, if the backward somersault is completed quickly. If the procedure is performed slowly, the air will escape into the spinal canal.

The Forward Somersault

If the air escapes into the spinal canal, it may be brought into the basal cisternae by turning the patient again, but now in the opposite direction, as indicated in Figs. 2 b and 2 c. If there is no obstruction, the air will cross the basal cisternae to the surface of the cerebral hemispheres (Fig. 2 c). If the air lies in the spinal canal, it may be necessary to bring the patient into a more upright position (Fig. 2 d).

The method described may also be used to spread the air into the subarachnoidal space on the surface of the cerebral hemispheres, in cases in which no obstruction is suspected. This may be useful in order to obtain a representation of the brain surface. An example of the results is shown in Fig. 5 in the author's previous paper (Acta radiol. 34, p. 403). In this, Fig. (a) represents a film taken after the injection of air by cisternal puncture, and (b) a film obtained after making the patient turn a backward and forward somersault successively.

It may be desirable to have all the air spread over the surface of the cerebral hemispheres in order to obtain rapid resorption.

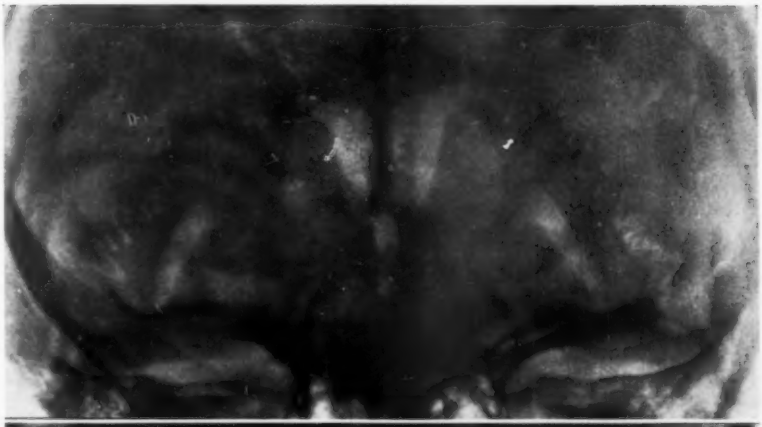


Fig. 5

Fig. 6

Fig. 5. Both inferior horns filled simultaneously after forward somersault. Normal case.
Fig. 6. Both inferior horns filled after forward somersault. Temporal glioma on the left side causing a slight impression of the inferior horn.

Forward Somersault to Fill Both Inferior Horns Simultaneously

The forward somersault as described above, may be applied in order to get a small amount of air into both inferior horns simultaneously. How this is performed is shown in Fig. 3.

After having collected all the air in one of the anterior horns (Fig. 3 a, 3 b and 3 c), the head of the patient is brought into an over-hanging position in order to distribute the air into both anterior horns (Fig. 3 d).

The patient is now returned firstly to the upright and then to the prone position (Figs. 3 e and 3 f). Following this, if the patient is made to perform the forward somersault, all the air will be distributed over both inferior horns (Figs. 3 g and 3 h).

The results of the procedure is illustrated in Figs. 4 and 5. As the procedure enables us to examine both the inferior horns simultaneously, we can easily detect minute deformations and displacements. Fig. 6 depicts the results in the case of a temporal glioma which caused a slight impression of the inferior horn.

During the Symposium Neuroradiologicum a larger series of examples was shown. The practical performance of the method and the fact that it does not give rise to great difficulties in adult patients was demonstrated by means of a cinematographic film.

SUMMARY

As already described in a previous paper in this journal in French, the third and fourth ventricles as well as the basal cisternae and the brain surface may be examined by means of small quantities of air, by making the patient turn a complete backward somersault followed by a forward somersault, or at least by making the head of the patient describe such movements.

In the present paper the author further describes how it is possible to depict both inferior horns simultaneously, after having distributed a small amount of air to both inferior horns by means of the forward somersault.

ZUSAMMENFASSUNG

Sowie schon in einer früheren französischen Veröffentlichung in dieser Zeitschrift beschrieben wurde, können der dritte und vierte Hirnventrikel sowie die basalen Cisternae und die Subarachnoidalräume an der Konvexität des Gehirns mit einer kleinen Luftmenge untersucht werden, dadurch, dass man den Patienten vollständig hintenüber resp. vornüber umwendet, wenigstens den Kopf des Patienten eine übereinstimmende Drehung ausführen lässt.

In der vorliegenden Veröffentlichung wird ausserdem beschrieben, wie man die beiden Unterhörner gleichzeitig abbilden kann, nachdem man die kleine Luftmenge, mittels einer vollständigen Drehung vornüber, über beide Unterhörner verteilt hat.

RÉSUMÉ

Dans une communication précédente l'auteur a décrit comment il est possible d'explorer le troisième et le quatrième ventricule, ainsi que les citernes basales et la convexité des deux hémisphères, en faisant subir au malade une culbute complète en arrière, respectivement en sens inverse, ou en tournant sa tête de façon analogue.

Dans cette communication-ci, l'auteur décrit, comment il est possible de photographier simultanément les deux cornes temporales, après avoir enserré une petite quantité d'air dans les deux cornes temporales, en faisant subir au malade une culbute en avant.

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DISCUSSION

OF THE ENCEPHALOGRAPHIC PAPERS

B. Falk:

I would like to point out the value of encephalography in the investigation of pontine gliomata if the encephalography is performed according to our technique at the Serafimerlasarettet, as described by LINDGREN. If the examination is carried out on those principles a differentiation between extra- and intracerebral expanding lesions is obtained without difficulty in practically all cases. Vertebral angiography is not the only radiological method of differentiation between a pontine glioma and a meningioma of clivus. It is also possible with encephalography, as pointed out by LINDGREN. The pontine glioma is usually symmetrical and therefore the aqueduct is lying in the midline. Exceptionally the tumour is asymmetrical and the aqueduct is thus dislocated sideways. LYSHOLM has published such a case. In such cases it is impossible to determine by ventriculography if there is a pontine glioma or a tumour in the cerebello-pontine angle, but a differential diagnosis is possible by means of encephalography including the examination of the cisterns of the posterior fossa.

G. Ruggiero:

Lumbar encephalography is a valuable procedure in the diagnosis of tumours in the posterior fossa. Among the conclusions of a study of 71 cases of posterior fossa meningiomas carried out in the Roentgen and Neurosurgical Departments of Serafimerlasarettet (the radiologic results were preliminary reported at the Congrès de Neuroloieg de Langue Française in Paris in August 1952), the author (with CASTELLANO) found that lumbar encephalography is the only way to differentiate with certainty a clivus meningioma from a pontine glioma.

In the case shown in figs. 1—4 lumbar encephalography is diagnostic, since, by reason of the backward displacement of the pontine cistern and the upward and backward displacement of the interpeduncular cistern, it demonstrates that the lesion is extracerebral and situated anterior to the pons. Moreover, it shows that as the left cerebello-pontine cistern is not filled, the lesion is expanding towards the left side.

Fig. 1. Clivus meningioma; the aqueduct, arch-shaped and slightly dilated is, together with the fourth ventricle, displaced backwards. The arrow is directed at 'Twining's point'.

The lesion cannot be a tumour arising in the cerebello-pontine angle, because such a tumour, producing non-filling of a cerebello-pontine cistern must also displace the aqueduct and fourth ventricle to one side. On the other hand, an intrapontine tumour which grows laterally and invades the cerebello-pontine cistern, usually produces an encephalographic appearance consisting of deformity of the cistern mainly in its medial part.

Another case is shown in figs. 5—6. It is a case of a meningioma which could not strictly be called a posterior fossa tumour because its site of attachment was the dura of the Gasserian region; the tumour was, however, expanding extensively into the posterior fossa.

Lumbar encephalography proved to be very useful in another verified posterior fossa tumour observed in the Roentgen Department of the Neurosurgic Clinic of the Hôpital St. Anne, Paris, and where for some months, in cases of brain tumours, I performed lumbar encephalography employing the technique acquired at Serafimer Lasarettet during a rather long study visit. The patient, a man of about 45, had developed severe symptoms of intracranial hypertension with a high degree of papill-oedema. The ventriculography performed had not been considered satisfactory for diagnosis. Following the ventriculography, the patient's condition was becoming worse and exploration of the posterior fossa was

Fig. 2. The fourth ventricle and the aqueduct lie in the mid line; the right cerebello-pontine angle is well filled, but the left is not.

Fig. 3. Only the superior part of the pontine cistern is filled with air; it is displaced backwards together with the interpeduncular cistern which is displaced also upwards.

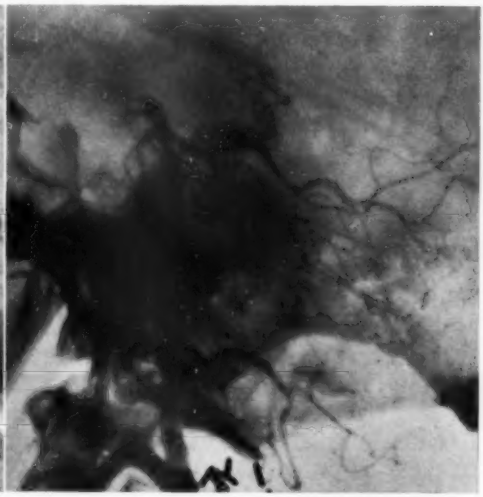


Fig. 4. Vertebral angiography, performed after the exploration and decompression of the posterior fossa, reveals marked backward displacement of the basilar artery.

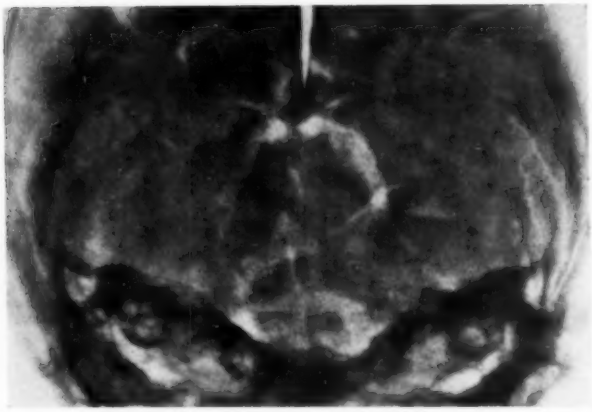


Fig. 5. Meningioma of Cavum Meckelii expanding into the posterior fossa. P.—a. view; no filling of the ventricular system; the tumour clearly outlined by the air in the cisterns. The left cerebello-pontine cistern is poorly filled and the interpeduncular cistern is displaced upward and to the right, being incompletely filled on the left side. The left ambient cistern is di-lated and displaced slightly upwards.

not carried out. Ventriculocisternostomy was performed. After some time the papilloedema disappeared and the condition improved considerably. After three or four months slight headache returned and it was decided to perform lumbar encephalography. I did not succeed in filling the ventricular system, but the appearances of the cisterns were sufficient to assume the presence of a space-occupying lesion in the posterior fossa. These appearances consisted of flattening from behind of the pontine cistern, suggesting the presence of a tumour in the posterior fossa, and a deep impression in the cisterna magna below the foramen magnum, indicating herniation of the cerebellar tonsils. The side of the lesion could also be determined by the fact that the anterior part of the cisterna magna, *i. e.* the vallecula cerebelli, was displaced upwards and laterally, and appeared in the films as a darker zone in the cisterna magna. On these encephalographic findings, operation was performed and an intracerebellar tumour successfully removed. The tonsils were markedly herniated.

In my opinion this case was also important from a neurosurgical standpoint because it demonstrated the absence of relationship between papilloedema and herniation of the tonsils, and, moreover, that marked herniation of the tonsils can exist in patients whose general condition is good. This last fact may explain why sometimes the patient's condition

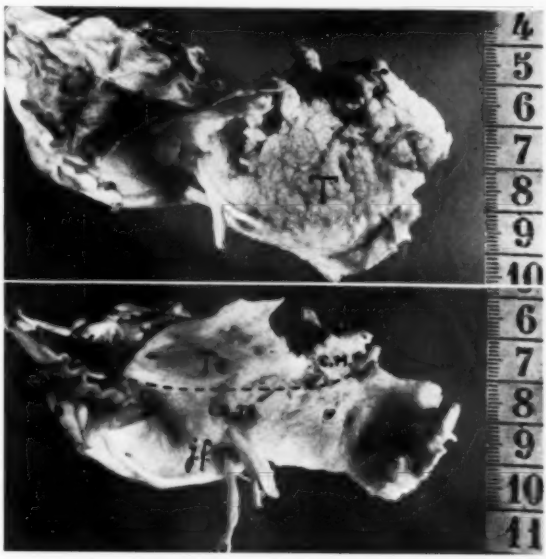


Fig. 6. Anatomic specimen of same case. The tumour appeared firmly adherent to the clivus, but was actually attached below — and only to the dura of the cavum Meckelii.

T = Tumour.
Te = Teutorium.
i. a. m. = internal auditory meatus.
j. f. = jugular foramen.
C. = Clivus.
c. m = Cavum Meckelii.

deteriorates after ventriculography not immediately followed by operation. I have personally made this observation in a case of a spinocranial tumour at the Hôpital St. Anne. The patient was suffering from Recklinghausen's disease and a tumour, probably a neurofibroma, was found at autopsy attached to the dura at the level C1—C2 and firmly adherent to the dens of the epistropheus.

CRANIAL TOMOGRAPHY IN NEURORADIOLOGY
TOMOGRAPHY OF THE BASE OF THE SKULL

by

R. Bourdon

on behalf of

Drs. *Bourdon*, *Fischgold*, Mme *Gilles*, Drs. *Herdner*, *Lenzi*, *Lombardi*, *Mascherpa*, *Oliva*, *Piazza*, *Porcher* and *Vallebona*

Tomography of the base of the skull is an up-to-date subject and in this paper we propose to review the technical and practical considerations as well as our own results.

The orbit, the olfactory fossa, the spheno-orbital area, the temporo-sphenoidal fossa, the sella turcica, the temporal bone and the posterior fossa with the cranio-vertebral joint, are the primary regions of interest from the anatomic viewpoint. The interesting work of the Italian authors on tomography in connection with gaseous contrast in the study of the cisterna basalis, must also be stressed.

The employment of tomography necessarily demands different techniques although with a common purpose: to obtain better, and as complete as possible, information on normal and pathologic structures. We are much indebted in this connection to the work of Bocage, Ziedses des Plantes, Vallebona, Herdner, and Jacques Porot, to whom it would be difficult to give adequate recognition. As Herdner pointed out, every technique has to be suited to the necessity of demonstrating the situation, depth, density and heterogeneity of a structure. Most of the results here reported were obtained by simple means: immobilization of the patient, and the movement of the tube and film through an angle of 50° to 60°.

On the whole, the optimum thickness of the laminagrams was 5 mm with a focus-distance of 1 metre and a longitudinal or sinusoidal type of anode displacement.

Many difficulties arise as regards definition and this seems to be a problem more for the physicist. The radiologic examination is one brick in the diagnostic building which is the work of many specialists, the end object being to yield a more complete diagnosis by a simple method of investigation. In most cases, the frontal and sagittal views are found to be the most satisfactory; the horizontal plane seldom requires investigation. The projection should approximate to the standard in order to simplify the procedure and its repetition.

The orbit. The radiologic examination of the orbit raises special problems, but we feel that tomography yields a definite advance. With 50° of tilt, a fair representation of the bony structure and satisfactory detection of pathologic changes may be obtained.

Tumours causing exophthalmus are best explored by tomography in order to obtain information regarding the primary site of the lesion. A special method of investigation, tomography with gaseous injection, is employed at the Quinze-Vingt Hospital in Paris. The injection is made either into Tenon's Capsule or into the retro-bulbar space and produces interesting results.

With the same end in view, the Sainte Anne Neuro-Radiologic Centre has applied tomography in numerous cases of unilateral exophthalmus of tumour origin. These include optical, olfactory or sphenoidal lesser wing meningioma, ethmoido-frontal mucocele and carotid aneurysm. The sagittal or frontal section may reveal collapse of the internal orbital wall (os planum sign), lesser wing, anterior clinoid process or cribriform plate modifications and, in some cases, changes in the lateral wall of the sphenoidal sinus. Tomographic studies in 27 unilateral exophthalmus cases of tumour origin led to the following observations:

1) The discovery of weak points in the orbital walls (internal and superior wall and floor). 2) Reactions in the ethmoido-nasal sinuses. 3) Capacity variations of the orbit with compensatory increase from tumour growth. 4) Adjoining structure alterations. The inferior orbital fissure, optic foramen and lacrimal groove, may be also explored by tomography in cases of abnormalities, trauma, infection or new growth.

The requirements of tomography are varied. In order to visualise the inferior orbital fissure for instance, the sub mento-vertical projection has to be used; for the lacrimal groove, a frontal projection. The unsatisfactory view obtained of the superior orbital fissure is due to the fact that this formation is difficult to include in a single plane.

Olfactory Fossa. Ordinary and tomographic investigations of the olfactory fossae situated on each side of crista-galli are especially important for a complete and early diagnosis in traumatic, inflammatory and,

above all, neoplastic conditions. The latter investigation may be performed together with encephalography, as is the practice at the Neurologic Institute of Milano which has mostly contributed to this method of examination.

Three anatomic levels in the anterior cranial fossa: the orbital, the fronto-ethmoidal and that of the cribriform plates, must be very clearly defined in order to show an olfactory meningioma. It is a point of the utmost importance that the tomograms in the frontal or sagittal planes show clearly the olfactory fossae, the nasal fossae and, above all, the crista-galli. Information based upon calcifications, or hyperostosis or erosions of the anterior clinoid process or basi-occiput which may appear in this condition in ordinary films, may be considerably augmented by tomography. This my reveal: 1) Extension of the tumour displacing the crista-galli, widening the olfactory fossa, bulging through the cribriform plate and pushing aside the lateral masses of the ethmoid, and sometimes interfering with the transparency and shape of the ethmoidal cells. 2) Destruction of the superior part of the perpendicular plate which indicates involvement and spread of the tumour at this level. In a few instances, the tomographic examination may be employed with arteriography or a gaseous examination. In other words, by removing the overlying planes, tomography improves detail in the front view giving a clearer appearance to any destruction of outline in the olfactory fossa or blurring of the ethmoido-frontal cells. This mode of investigation of an olfactory meningioma has progressed by revealing the action of tumour pressure on the crista-galli and the olfactory or nasal regions.

The spheno-orbital area is revealed as a fundamental zone of the base of the skull. Changes may be encountered in the optic foramen and superior orbital fissure, secondary to a tumour causing abnormalities of the eye and orbit and their nerves and vessels.

The Sella Region. The anterior clinoid processes are essential landmarks in this connection. It is therefore of great importance to distinguish signs of global hypertension, which appear at the level of the middle fossa, from local signs originating at the site of the anterior clinoid process. In this connection, tomography is a good method of comparing the clinoid processes and obtaining a more precise conception of their relation with the optic groove, sphenoidal sinus and superior orbital fissure. Hence, it is a means of determining the symmetry of the clinoid processes as well as the distance between them. In pathologic conditions (such as lesser wing meningioma, chiasma-glioma, internal carotid aneurysm etc.) an upward or downward displacement, erosion or thinning of the anterior clinoid process may be encountered. For these reasons, tomography completes with great efficiency the standard ex-

amination in patients with both intrinsic and extrinsic ocular signs and is a means of checking the boundaries of the hypophyseal fossa, the morphology and symmetry of the clinoid processes and any increase in the inter-clinoid distance. From the roentgenanatomic point of view, it must be remembered that: 1) General cranial hypertension has little effect on the anterior clinoid processes and will resemble distant pressure by hypophyseal tumours. 2) Local pressure signs may be discovered in the tomograms. 3) Clinoid symmetry and inter-clinoid distance (shown in 40 normal cases to be 24 to 28 mm) has to be estimated in every pathologic condition in this region.

The abundance of the literature on the radiologic investigation of the sella turcica emphasizes its prevalent interest. Tomography is able to yield better information on the pathologic aspect in cases of tumour expansion either towards the optic chiasma, floor of the sella turcica or cavernous sinus. For a long time great use has been made of sagittal tomography (Ziedses des Plantes). But it seems to us that frontal tomography may afford more complete information. The investigation is executed in the occipito-frontal position. The distance between the sections is 5 mm, the anterior passing through the tuberculum sellae and anterior clinoid process, the posterior through the posterior clinoid process and dorsum sellae. The medial section, 6 to 7 cm from the fronto-nasal plane, is the most useful. The study is of special interest for information regarding the floor of the sella, the sphenoidal sinus and temporo-sphenoidal fossa, that is to say, the cornerstone of the arch of the middle fossa. The superior margin of this region may appear dome-shaped, bilocular, flat or hollow with lateral margins adjoining the cavernous sinus. Three main signs will be evaluated: 1) the height of the floor of the sella, 2) the interclinoid distance, 3) the continuity of level between the superior margin of the petrous pyramid and superior margin of the floor of the sella. The frontal examinations as practiced on a large scale at the Ste Anne Hospital in Paris, were directed to: 1) The morphologic study of the sella turcica and its variations in endocrine disturbances. 2) Analysis of the degree of destruction usually unilateral, of the double-shaped contour or the distant effects of pressure in various cases of adenoma (chromophobe, mixed or basophilic), craniopharyngioma, internal carotid aneurysm, temporal fossa, or posterior fossa tumours. 3) State of the dorsum sella which appears to be a weak point while the lateral margins are resistant. This is the region where early signs have to be looked for.

Temporo-Sphenoidal Fossa. Various foraminae are situated in the temporo-sphenoidal fossa, and as the antero-inferior part of this region lacks resistance, frontal, and especially sagittal, tomography assume a

special interest. It provides better evidence of anatomic changes in cases of cerebral hypo- or hyperpressure (unilateral cerebral atrophy, plagiocephaly, hydrocephalus etc.) with their specific signs (LEFEBVRE).

Secondary to the pressure variations, either a decrease or expansion of the hemicranium with shrinking of the temporo-sphenoidal fossa, or a deepening of the temporo-sphenoidal fossa with parietal thinning will be noted. Such information is particularly interesting in epilepsy which so frequently involves the temporal lobe.

The Petrous Bone. The tomographic examination of the petrous bone produces, as in the standard examination, various kinds of problems. These originate in the anatomic complexity and the uneven density of the great part of the temporal bone. Many authors have attempted to make theoretic, technical and practical approaches to this question (PIAZZA, ZIMMER, MUNTEAN, GRILLI, BULLO).

At the Quinze-Vingt Hospital in Paris, the investigations are carried out with 3 mm sections; it seems most important to compromise between the value of the angle and the focus-film distance to obtain films of satisfactory quality. We feel this method of investigation will be found to be justified in the future but will be used with definite indications obtained from ordinary films taken to give maximum information.

The Posterior Fossa. The pathology of the posterior fossa is still obscure and in this region tomography is, in some instances, able to offer a valuable contribution; this is particularly so in cases of atypical relationships between the skull and the cervical spine and deformities due to developmental abnormalities. Bony abnormalities explain the appearance of the basilar impression. It is at the level between the occipital condyle and the mastoid process that the deformation takes place, and the plane normally directed downwards and inwards comes to lie upwards and inwards. Accordingly it will be appreciated that many clinical syndromes may result, bearing in mind the various nerves and especially those of the jugular foramen and anterior condylar canal, which are situated in this region. Many works have been devoted to this particular region and various indexes proposed. We recognize the Chamberlain—Mac Gregor line, extending from the hard palate to the posterior fossa, as being very useful in the sagittal view. But in the experience of the Paris school, the bi-mastoid and the bi-digastric lines are of utmost importance.

From investigations carried out, it is evident that frontal and sagittal tomography in selected planes is the best means of obtaining a satisfactory demonstration of the deformity. This is true either in cases of

a pure basilar impression or in association with atlas occipitalization or fusion of cervical vertebrae with spina-bifida. A basilar impression may be associated with foramen magnum invagination resulting in a reduced posterior cerebral fossa capacity and narrowing of the jugular foramen and anterior condylar canal. On lateral views, the dorsum sellae and basi-occiput are very satisfactorily demonstrated.

In the basi-occiput at the spheno-occipital junction, unusual conditions associated with anatomic and embryologic conditions, may occur. The parts played by the spheno-occipital synchondrosis and the notochord vestiges explain the incidences of special tumours at this site (chondroma and chordoma). In these conditions, profile tomography is best in demonstrating the Boogard basal angle or structural modifications of condensing, eroding or cavitating types. (An interesting case was shown at the Exhibition of the Symposium by KNUTSSON.) The cranio-cervical joint is also of importance in this local investigation. Italian authors describe the value in this region, of not only sagittal or frontal tomography, but also of axial transverse tomography. This special procedure would be indicated in cases of congenital deformities, trauma, tumours or post-operative conditions to show: 1) the occipito-atlantal joint, 2) the occipito-axoid joint, 3) the atlanto-odontoid joint. By its employment, a very clear representation is obtained of changes at the base of the skull and lateral aspect of the occiput. Furthermore, a survey of the pathology may be made in cases such as platybasia, atlanto-axoid fusion or dislocation and particularly of a basilar impression either in its congenital forms or secondary to osteomalacia, Paget's disease, a tumour, infection or trauma (MCRAE, KNUTSSON and workers at Serafimer Lasarettet).

By associating the injection of a gaseous contrast medium with tomography we are in a position to widen the range of the investigation. Encephalography in conjunction with this method seems to apply specially to hypophyseal fossa, peri-hypophyseal, temporal lobe or chiasmatic tumours.

To treat so vast a subject in such a limited space may appear a little presuming, the more so as we present the result of different workers having a common endeavour, that is, to make this special diagnosis more precise and more complete by a full radiologic survey including tomography. Theoretical and technical considerations have been accepted without exclusion with the desire of obtaining films giving the maximum of information with the minimum of complexity in devices and their handling. That is why in some departments, we limit the technique to simple projections so that we can include tomography as a routine examination.

Conclusions

1) Tomography must be protected from the double danger of asking too much or too little from it.

2) This method of investigation can be efficient only after a full examination by standard methods combined with an efficient clinical examination.

3) There are special indications for tomography, for instance, in the examination of the sella turcica, where it produces more and different information than the ordinary films. In many cases this examination is easier than oblique views.

4) The problem of elucidating and evaluating the symmetry of the deeply placed formations at the base of the skull may more easily be solved by tomography.

5) Tomography may also prove of value in the investigation not only of local deformations but also of distant effects in association with angiography, ventriculography and encephalography.

We feel that tomography in neuroradiology has a definite part to play and that its advantages and possibilities for obtaining greater and more detailed information must lead to its more widespread employment.

At the Symposium Exhibition many films were shown demonstrating the aforementioned facts. In the author's opinion tomographic films lose many of the essential details by reproduction, and no illustrations have therefore been included in this article.

SUMMARY

The authors deal with the various regions of the base of the skull in turn and their suitability for tomographic investigation. The importance of the method as a supplement to ordinary radiography is pointed out; it is especially valuable in the examination of the sella turcica.

Tomography may be employed in association with angiography, encephalography and ventriculography and, in the case of the orbit, after a special gaseous injection. Various results and observations are summarized and details of technique given.

ZUSAMMENFASSUNG

Die Verf. besprechen die verschiedenen Abschnitte der Schädelbasis der Reihe nach bezüglich ihrer Eignung für tomographische Untersuchung. Die Bedeutung der Methode als Supplement der üblichen Röntgenuntersuchung wird hervorgehoben; sie ist für die Untersuchung der Sella turcica besonders wertvoll.

Die Tomographie kann im Verein mit der Angiographie, der Enzephalographie, der Ventrikulographie und bei Untersuchung der Orbita nach spezieller Luftinjektion angewendet werden. Verschiedene Resultate und Beobachtungen werden zusammengestellt und Einzelheiten der Technik werden beschrieben.

RÉSUMÉ

Les auteurs étudient successivement les différentes régions de la base du crâne et les possibilités de les examiner tomographiquement. Ils insistent sur l'intérêt de cette méthode comme complément de la radiographie ordinaire; elle est particulièrement précieuse pour l'examen de la selle turcique.

On peut employer la tomographie en association avec l'angiographie, l'encéphalographie et la ventriculographie et, pour l'orbite, après une injection d'air spéciale.

Les auteurs résument quelques résultats et observations et donnent des détails de technique.

DISCUSSION

OF THE TOMOGRAPHIC PAPER

Claude M. Gros:

Since the introduction of cisternography by BELLENI in 1940, the method has reached its aim — to be a routine measure in the roentgen investigation of the subarachnoid space. We reported our first steps in tomocisternography at the Société d'électroradiologie du Littoral méditerranéen in January 1952. We now have a wider experience of the method which has become much used by our neurosurgical team.

We employ 20 cc of gas, injected by means of lumbar puncture. The patient sits with the head in hyperextension and no fluid is removed. The gas is followed on the fluoroscopic screen in order that the most suitable moment for obtaining films may be gauged. We usually take a standard lateral view and three tomographic films (one median and two paramedian, 1 cm to the right and left, respectively) 1—5 minutes after the injection. If the cisternae are blocked, it is sometimes useful to obtain further films later.

If we compare a tomocisternogram with a standard cisternogram, we see that detail is much improved in the former. The optic tracts, hypophyseal stalk and basilar trunk with its branches are shown with particularly good detail.

It seems to us that the method is useful in the elucidation of the anatomy of the basal cisternae. I was, as a neurosurgeon, at first afraid of the possibility of decompensation of these patients after lumbar puncture. Actually, with the Neurosurgical Department near at hand, the method caused us no anxiety. We have used the method also in cases with clinical evidence of high intra-cranial pressure.

B. G. Ziedses des Plantes:

I was deeply impressed by the films which I saw in the scientific exhibition and during the contribution on planigraphy. At the same time, I would like to emphasize that under all circumstances it is necessary for the roentgen beam to be tangential to the part of the object which it is desired to include in the radiogram.

In planigraphy where the roentgen rays are steadily changing direction, it is necessary that these should be tangential to the object during the exposure. It will therefore not be possible to obtain a precise image of

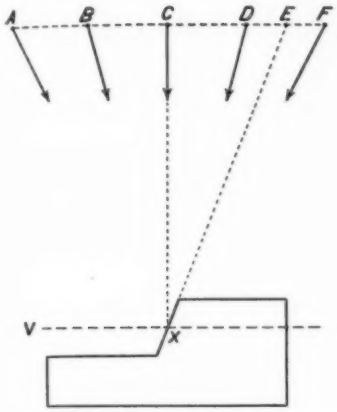


Fig. 1. If the tube is moved from A to F a clear image of point X of plane V is obtained. If the tube is moved from B to D, or perpendicularly to C, no image of point X is produced.

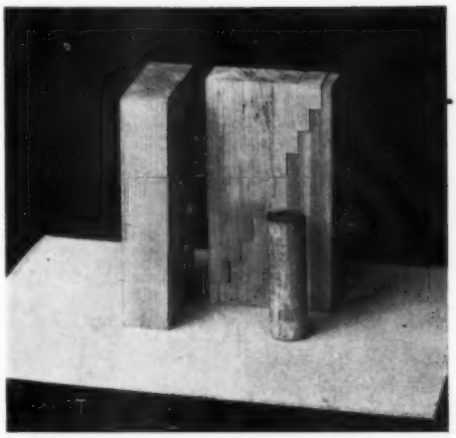


Fig. 2. The object for the experiments.

a body section if the tube is moved in only one direction. If for instance, one wishes to produce an ordinary radiogram with a vertical projection of the object (Fig. 1), the focus of the tube remaining at point C, one will not produce any representation of point X. If, during the procedure of obtaining an image of the plane, the focus of the tube is moved from B to D, no image of point X will again be obtained. If, however, the focus is moved from A to F and on its way passes point E, an image of point X will be produced.

This was fully explained and illustrated in this journal in 1932.

If the tube is not moved in the direction A to F, but perpendicular to the paper through the point C, one obtains the same negative result as if the focus stayed at the point C.

One often reads that the purpose of planigraphy is to obtain films in which the parts of the object lying outside the plane represented are less visible. It must be emphasized that in a planigram we not only see less of the object, but we see also more details of the parts of the object lying in the plane represented, viz. the oblique boundaries, which are not visible in the ordinary radiogram.

The results of the different movements of the focus are illustrated in Fig. 2 and Fig. 3.

In orthoplanigraphy the roentgen tube is fitted with a collimator, so that a rather narrow beam is used. Each part of the object will be pro-

Fig. 3 a. Ordinary radiogram of the object.

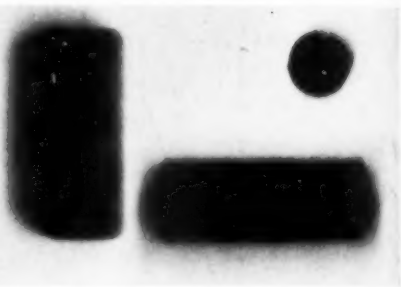


Fig. 3 b. The result of a linear movement of the tube and the film.

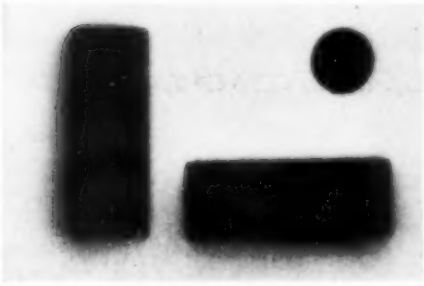


Fig. 3 c. The result of a spiral movement.

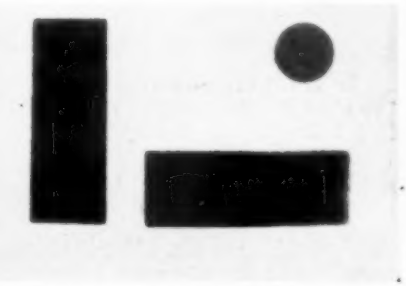


Fig. 3 d. The result of orthoplanigraphy.

jected from different but almost perpendicular directions. If the boundaries of the parts of the object, lying in the plane of section, have a nearly perpendicular direction, *e. g.* in the sagittal plane of the skull, we shall obtain a very clear image.

A few words may be added about the terms planigraphy and tomography.

In my first publication in 1931 on the procedure, I proposed the name planigraphy, to comprise all body section methods. I was at that time ignorant of the patents of BOCAGE and of POTES and CHAUSSÉ.

It was GROSSMANN in Germany who in 1935 emphasized that the correct procedure was to move the tube in one direction only and suggested the name tomography for what he claimed to be a new procedure.

As the word tomography is linguistically better, the speaker would agree to its use in the future, if GROSSMANN would not blame us for the confusion which might arise.

FROM THE NATIONAL HOSPITALS FOR NERVOUS DISEASES AND THE NEUROLOGICAL DEPARTMENT OF ST. GEORGE'S HOSPITAL, LONDON, ENGLAND

SPINAL MENINGIOMAS AND NEUROFIBROMAS

by

J. W. D. Bull

Spinal meningiomas and neurofibromas together form quite the largest group of spinal tumours. They are of particular importance as they are nearly all benign and fairly easily removed surgically. If the diagnosis is made not too late the results are excellent. It would probably be no exaggeration to say that there are few, if any, more dramatic and satisfactory operations in the whole of surgery. Unfortunately, not infrequently, the correct diagnosis is so long delayed that irrevocable damage may be done to the spinal cord. Although this fact is well known, a recent case may perhaps be appropriately quoted. Not long ago I read an obituary of a well-known radiologist who at the height of his career began to lose the use of his legs and for the last sixteen years of his life was confined to a wheel-chair although courageously continued working to the end. Naturally being a medical man he was seen by many neurological experts, but the diagnosis defied them all and it was suggested that perhaps he had carelessly allowed himself too much roentgen radiation in the early days. He died of a coronary thrombosis and at autopsy a neurofibroma was found pressing upon the spinal cord.

Prior to the advent of radiology the diagnosis of these two tumour types was very difficult and was seldom made. That surgery should be attempted in those days was remarkable, but in 1883 Sir William Macewen of Glasgow removed a fibrous neoplasm from the spinal theca and in 1887 Sir Victor Horsley of London, on the suggestion of Sir William Gowers who made the diagnosis, successfully removed a fibromyxoma of the theca attached to the fourth thoracic nerve. But it was not until radiology was well established and neurosurgery more highly developed that the diagnosis and treatment of these cases became a commonplace.

In 1924 Carman and Davis of the Mayo Clinic analysed the roentgenograms of 119 cases of spinal tumour and found only three to be

positive (2.9 %). It was therefore felt that ordinary roentgen examinations, without the use of contrast medium, were not of much help. In 1923 SICARD and FORESTIER introduced myelography, with lipiodol as the contrast substance. This procedure made accurate localisation possible. Then a little later (1931) CAMP, ADSON and SHUGRUE, of the Mayo Clinic, stated, "We do venture the opinion that roentgenographic changes of bone can be demonstrated in 15 to 20 per cent of cases in which tumours arise from tissues within the spinal canal." This was an advance. Then in 1934 CAMP reviewed the films of all cases of spinal tumour seen at the Mayo Clinic from January 1st, 1930, to September 1st, 1933. He does not state the number of cases, but he found osseous changes in 50 %. 65 % of the neurofibromas and 11 % of the meningiomas showed bone changes. In a later paper (1941) CAMP revised his figure of osseous changes for all types of spinal tumour down to 30 %. In 1934 DYKE and ELSBERG, concerning themselves mainly with the interpedicular measurements of the vertebrae, found that 41 % of 70 cases showed a widening of the vertebral canal at the site of the tumour in antero-posterior films. This figure embraced all types of spinal tumour. ELSBERG in another paper published in the same year stated that 10 out of 18 (56 %) neurofibromas and 2 out of 25 (8 %) meningiomas showed changes on ordinary examination. He also pointed out that most meningiomas occur in women over 40.

These last papers, written nearly twenty years ago, are solid proof of the value of the roentgen examination, without the use of contrast medium, in the diagnosis of spinal tumours.

Material

The present material consists of 111 cases, mostly seen in the last six years. There were 59 cases of meningioma and 52 cases of neurofibroma. The ratio of these figures is in close keeping with that of RASMUSSEN, KERNOHAN and ADSON (1940), who reviewed 557 intraspinal neoplasms from the Mayo Clinic, mainly from the pathological aspect. Neurofibromas represented 29 %, meningiomas 25 % and no other single group over 11.5 %.

An analysis of my cases showed certain differentiating features between the two tumour types which are not radiological, but are important for the radiologist to appreciate when making a diagnosis.

Age Incidence: The meningiomas usually presented themselves later in life than the neurofibromas (Diagram 1). The average age at diagnosis was 50 years, while for neurofibromas it was 38 years. Over 90 % of the meningiomas were seen in patients over 35 years of age.

It will be seen in Diagram 1 that practically no age is immune from

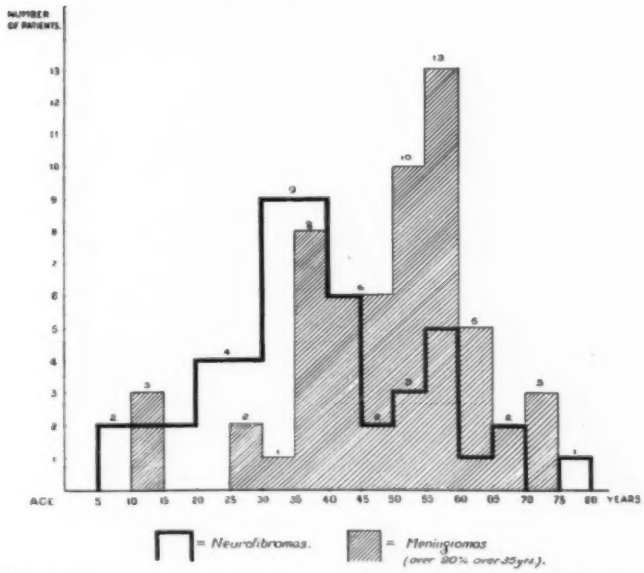


Diagram 1. Age distribution of meningiomas and neurofibromas.

either tumour, but there is a general trend for the meningiomas to manifest themselves later in life.

Sex Incidence: 85 % of the meningiomas were in women, but there was no marked sex preponderance in neurofibromas, there being 23 males and 29 females. The very great preponderance of spinal meningiomas in women is interesting, for the same state of affairs exists in meningiomas of the posterior fossa. Similarly the absence of sex preponderance is found in neurofibromas of the posterior fossa. Far the commonest type is, of course, the eighth nerve neurofibroma, a tumour probably as common as all spinal neurofibromas added together.

Situation in the Spinal Canal: Here again there was a difference. Nearly all the meningiomas occurred in the thoracic portion of the spinal canal while the neurofibromas were diffusely distributed. There was one exception, the absence of any neurofibroma on the first cervical nerve. Diagram 2 shows the distribution of the tumours. RASMUSSEN, KERNOHAN and ADSON found a similar distribution.

Radiological Features

Calcification and Ossification: This is such an important radiological sign that it may conveniently be considered first. None of the neuro-

Distribution of Tumours

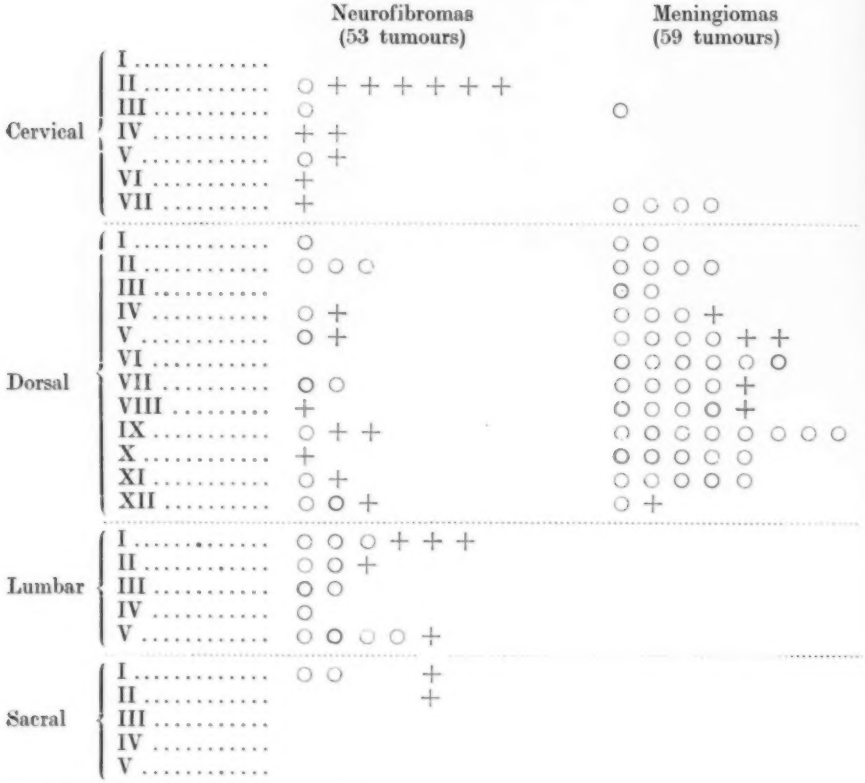

Neurofibromas
(53 tumours)
Meningiomas
(59 tumours)
Cervical
I
II ○ + + + + + +
III ○ ○
IV + +
V ○ +
VI +
VII + ○ ○ ○ ○
Dorsal
I ○ ○ ○
II ○ ○ ○ ○ ○
III ○ ○
IV ○ + ○ ○ ○ +
V ○ + ○ ○ ○ ○ + +
VI ○ ○ ○ ○ ○ ○
VII ○ ○ ○ ○ ○ ○ +
VIII + ○ ○ ○ ○ +
IX ○ + + ○ ○ ○ ○ ○ ○ ○
X + ○ ○ ○ ○ ○
XI ○ + ○ ○ ○ ○
XII ○ ○ + ○ +
Lumbar
I ○ ○ ○ + + +
II ○ ○ +
III ○ ○
IV ○
V ○ ○ ○ ○ +
Sacral
I ○ ○ +
II +
III
IV
V
+ = Ordinary roentgenograms: positive
○ = Ordinary roentgenograms: negative

Diagram 2. Distribution of tumours relative to skeleton.

fibromas were calcified and furthermore I am not aware of having seen calcification in any neurofibroma of the cranial nerves. On the other hand, calcification and/or ossification in spinal meningiomas is very common. This is readily apparent histologically. Unfortunately, I cannot give actual figures because calcification was not specifically sought for in the histological sections.

It will be appreciated that dense calcification is necessary before it will become visible in a tumour surrounded by such heavily calcified tissue as a vertebra. We always search most carefully for calcification

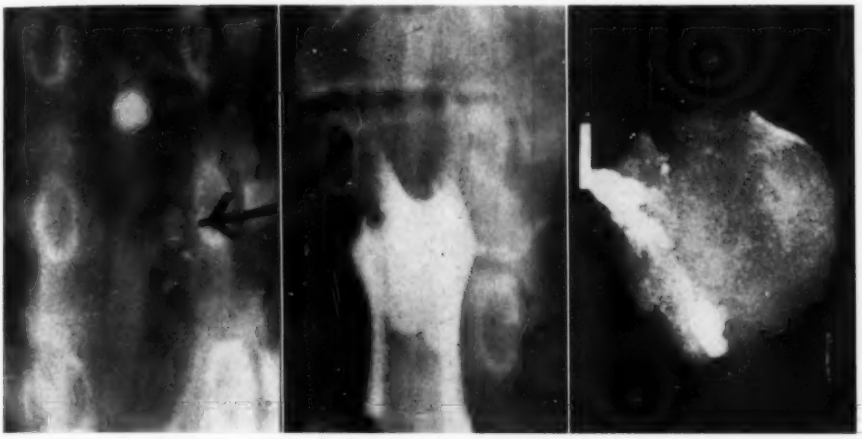


Fig. 1. Fig. 2. Fig. 3.

Fig. 1. Calcification (↑) medial to left pedicle of dorsal vertebra VII. (Tomogram) (A droplet of contrast substance lies cranially to the calcification).

Fig. 2. Myelogram. Same case. The contrast medium is flowing cranially and outlines the lower pole of the tumour.

Fig. 3. Radiograph of tumour after removal. Same case. The extensive calcification is clearly seen. The densely calcified portion could only be seen in the radiographs with the tumour in situ. (The tantalum clip provides a scale of measurement.)

within the spinal theca, but have been disappointed with the results. GRAY (1942) described one calcified and one ossified meningioma which he demonstrated radiologically. In a personal communication he informs me that, in the last ten years, he has not encountered this sign again although he has seen a number of spinal meningiomas. If the sign is present it is very helpful in making a firm diagnosis; it is not absolutely pathognomonic as other types of spinal tumour calcify in rare instances. Fig. 1 is an example of a calcified meningioma, the calcification being just visible. Fig. 2 shows the lower pole of the tumour outlined by positive contrast medium. Fig. 3 is a radiograph of the specimen after removal. It should be observed that only the very densely calcified portion was visible through the vertebra when the tumour was in situ.

It is a fact that calcification is very common in spinal meningiomas, but disappointly seldom is it visible in the films.

Again it is interesting to compare meningiomas of the posterior fossa. They occasionally calcify in this situation. The calcification can be seen much more easily than in the spine as there is less superimposing bone present.

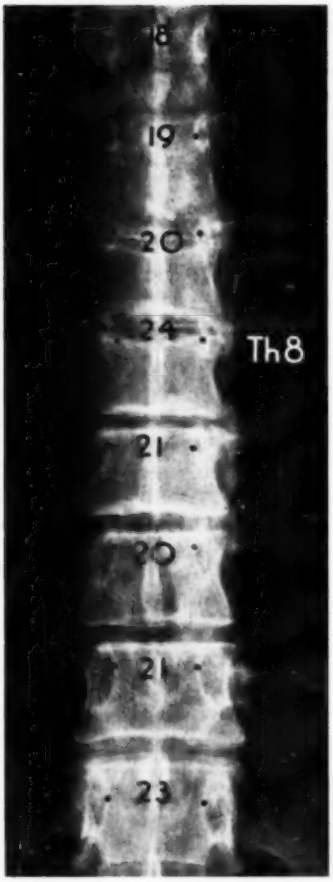


Fig. 4. Widening of interpedicular space at Th. 8.

The Pedicles: We are indebted to ELSBERG and DYKE for drawing attention to the great importance of the pedicles of the vertebrae in the diagnosis of spinal tumours. These authors drew a curve of the normal interpedicular measurements.

I personally do not attempt to remember the precise interpedicular measurements at the various vertebral levels. If one remembers that like the spinal cord, the bony spinal canal has a cervical and lumbar enlargement, the matter is simplified. I would add that the lumbar enlargement of the canal is continuous downwards, unlike the cord which terminates at the lower border of the first lumbar vertebra. It has been my experience also that interpedicular measurements at the thoracico-lumbar junction may be somewhat misleading, and more than once I have made a tentative diagnosis of tumour at this level, relying on the interpedicular distances, when in fact there has been no tumour. Gross changes are obvious, but minor changes may be best observed in about the first ten thoracic vertebrae.

When a definite increase in the interpedicular distance is present in a vertebra, this is nearly always evidence of the presence of a space-occupying mass within the spinal canal at that particular level.

Meningiomas

Analysis of the roentgen findings on examination without contrast.

Only six out of fifty-nine case (10 %) showed changes on ordinary roentgen examination. Five of these showed some increase in the interpedicular distance (Fig. 4) or actual destruction of a pedicle. In only two cases was calcification visible on the roentgenograms. One of these which showed no pedicular abnormality, has already been illustrated. Fig. 1.

Most meningiomas are situated intradurally or within the arachnoid

Fig. 5. The medium outlines the superior pole of an intradural tumour at Th. 8. The spinal cord is displaced to the right. (Ordinary films: normal.)

Fig. 6. Left-sided intradural meningioma completely outlined by the contrast substance in a case with incomplete spinal block. (Ordinary films: normal.)

space. This differentiation cannot be made radiologically and is unimportant surgically or pathologically. However about ten per cent are extradural (six out of fifty-nine in the present series). Extradural meningiomas tend to be malignant. They may be differentiated from the others myelographically. Only one of the six extradural tumours in the present series showed changes on ordinary roentgen examination and these consisted of a slight destruction of one pedicle.

Since it is agreed that only about ten per cent of meningiomas show changes in ordinary films, it is most important to resort to myelography in the diagnosis of such tumours.

Myelography

We use Myodil (manufactured by Glaxo, London) as the contrast medium. It is our opinion that it is a very benign substance and immediate or late complications are very rare, far more so than with lipiodol. At the moment I do not wish to discuss the relative merits of the various positive and negative contrast media used for myelography nor the relative merits of cisternal and lumbar injection of the positive contrast substances, except to say that when a complete block

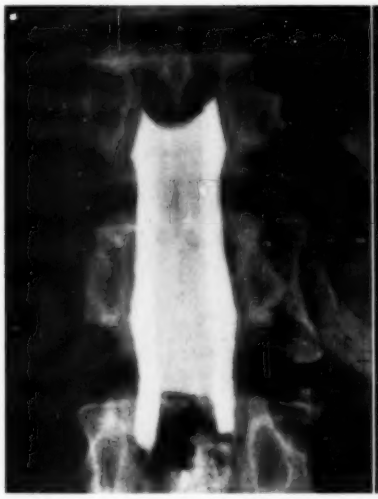


Fig. 7. A centrally situated tumour, the lower pole of which is outlined. The spinal cord is faintly seen within the column of contrast medium and is not displaced to right or left. (Ordinary films: normal.)

Fig. 8. Same case. The lateral projection shows the tumour to be situated anteriorly.

is suspected it is more comfortable for the patient to be examined after cisternal injection as then it is not necessary for him to be placed upsidedown.

We generally use about 5 ml of the medium, but if a complete block is strongly suspected we use considerably less. When the tumour lies to the right or left, the cord may usually be seen to be displaced to the opposite side. Fig. 5 is an example of a left-sided tumour. Fig. 6 shows a tumour completely outlined. Since none of the meningiomas lay below the twelfth thoracic vertebra, the spinal cord was in association with all of them. It is a little more difficult to differentiate tumours posteriorly situated from those lying anteriorly, Figs. 7 and 8. The tumours were seen myelographically to be situated as follows:

Right	26
Left	23
Anterior	5
Posterior	5

This grouping is somewhat crude since at operation some of the tumours were antero-lateral and others postero-lateral. But the really important

question for the surgeon is the number of tumours situated anteriorly. Naturally these are quite the most difficult to remove without damaging the cord. In this series, five, or a little under ten per cent, lay anteriorly. They had to be removed in small pieces by the surgeon and it was sometimes difficult to be sure in these cases that complete enucleation had been performed.

Extradural tumours can usually be diagnosed myelographically (Fig. 9). Both the contrast substance and cord are displaced.

One final point about meningiomas is that they are mostly not very large tumours. Unfortunately precise figures cannot be given here since volumetric measurements have only recently been made by our histologist. It would be natural to expect the tumours to be rather small since they nearly all lie in the small confines of the thoracic spinal canal. A tumour in this situation does not have to be very large before it presses on the cord and causes symptoms.

Neurofibromas

These produce a very different radiological picture from the meningiomas. Neurofibromas grow on spinal nerves or their root filaments and it is therefore necessary to consider certain anatomical relationships. When the nerve leaves the spinal cord it first has a subarachnoid course, short at the cervical end and becoming longer caudally on account of the increasing obliquity of the nerves. Next there is a short subdural part, thirdly an extradural intraspinal canal part, fourthly an intraforaminal part and lastly an extraforaminal-juxtavertebral part. Thereafter the nerve becomes too peripheral for a tumour mass growing on it to involve the spinal canal or cord, and is thus outside the scope of this discussion.

One would therefore expect, on ordinary examination, a variety of changes, which is precisely what one encounters.

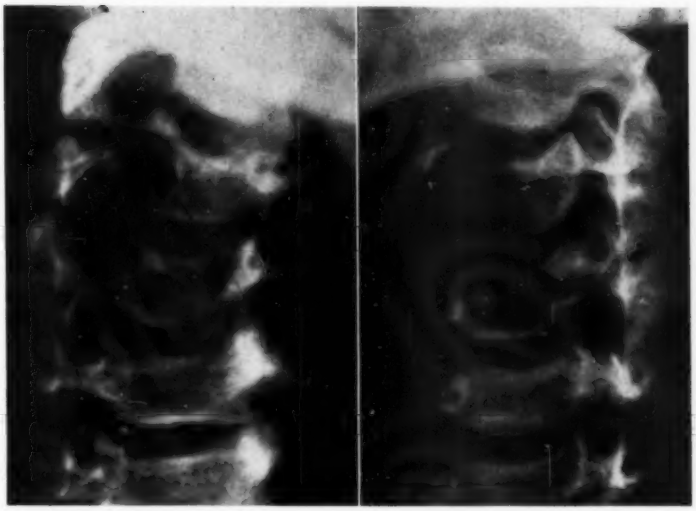
Neurofibromas may grow to a considerable size, sometimes, as large as a mature foetal head, and may well involve more than one of the five anatomical parts described. Indeed they often do. Such tumours are usually given the term 'dumbbell'. They are generally bilobate, the two lobes being connected by a narrow isthmus which is usually produced by bone pressure, classically the vertebral exit foramen.

Reconsidering the anatomy one would expect two types of neurofibroma not to produce in the ordinary films, changes of bone:— (a) those which are intradural and not large enough to splay the pedicles and (b) those which are entirely extraforaminal. This is in fact what we do find, except that the extra-, yet juxta-, foraminal tumours in the dorsal region may erode the head and neck of the adjacent ribs.

Fig. 9. Left-sided extradural meningioma at Th. 1. The contrast was flowing cranially. (Ordinary films: normal.)

Fig. 10. Extradural neurofibroma on second cervical nerve. Note wide separation of laminae (C. 1—C. 2) caused by the tumour.

Fig. 11. Normal case to show normal relationships of laminae of atlas and axis.



a. b.

Fig. 12. (a) Right-sided extradural neurofibroma on C. 4. Note widened foramen. (b) Normal exit foramen on left side, seen in the left oblique projection.

This group is outside our discussion if the spinal canal and cord are not involved.

Of the 53 tumours seen in 52 cases (one case had two tumours), 24 (45 %) produced changes and 29 no changes in the ordinary films.

Abnormal findings on ordinary examination

Of the 24 cases with abnormal roentgen findings, 18 were extradural and could all be described as dumbbell tumours to a greater or lesser degree. These 18 extradural cases may conveniently be analysed first and considered according to their anatomical site: cervical, thoracic, lumbar or sacral.

Cervical Tumours: No less than six (one third) of these tumours grew from the second cervical nerve root and widened the interlaminal space between the atlas and axis. One must remember that there is no true intervertebral foramen, as exists down the remainder of the spine, at this level. This separation of the laminae was plainly seen in the lateral views. It is particularly well seen in the case illustrated in Fig. 10. Fig. 11 shows a normal spine for comparison.

Three others lay in the cervical region, widening the exit foramen at C. 3—4, C. 4—5 and C. 6—7 respectively. Between C. 3 and C. 7, unlike C. 1 and C. 2, the lesion is usually only seen satisfactorily in oblique views. The great importance of oblique projections cannot be too strongly stressed as Fig. 12 demonstrates. One half of extradural tumours with changes in the ordinary films lay in the cervical region.

Thoracic Tumours: Seven lay in the thoracic region, five eroding both pedicles and ribs. These signs combined are clear indications of a dumbbell tumour, whether a soft tissue shadow can be seen or not. The appearances are so well known that illustration is unnecessary. One case showed destruction of the inferior half of one pedicle and widened exit foramen. The remaining case merely showed widening of the interpedicular space, so that a specific pathological diagnosis could not be made.

Lumbar Tumours: Only one extradural tumour lay in the lumbar region. There was a widening of the pedicular space, destruction of the posterior aspect of the vertebral body and widening of the exit foramen. The same changes were seen to a lesser degree in the twelfth thoracic vertebra.

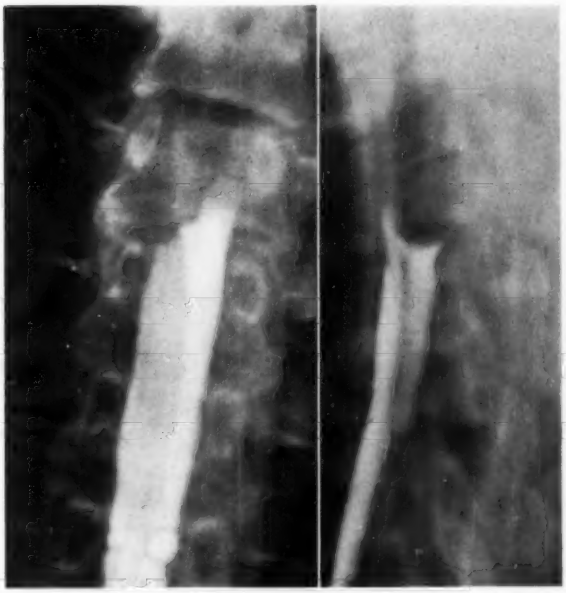
Sacral Tumours: Again there was only one case. The tumour was very large, extending from the top of L. 5 to the lower margin of S. 2. The roentgenograms showed a gross widening of the canal in this region. This was the only case in which more than two vertebrae were eroded; when this occurs the diagnosis of neurofibroma should only be made with extreme caution.

There were six other tumours, all intradural, which produced changes on ordinary examination. Two were cervical, lying at the level of C. 3 and C. 5, respectively, and both showed widening of the exit foramina. On these grounds they were thought to be dumbbell tumours, but in fact were not. This is a confusing point.

One lay at Th. 12, had widened the interpedicular space and eroded the back of the body of the vertebra. Two others were situated at L. 1 and one at L. 3. All three of these tumours widened the interpedicular space. In such cases one cannot state whether the tumour is intradural or extradural.

Neurofibromas with Normal findings on ordinary examination

There were 29 neurofibromas which failed to produce changes on ordinary roentgen examination. It is interesting to consider why this was so. It would be reasonable to expect that these tumours were not of the dumbbell type, but purely intradural and thus very similar in anatomical situation and shape to the meningiomas. This indeed usually



a. b.

Fig. 13. Intradural neurofibroma at Th. 7 on the left side. a) Spinal cord displaced to right. b) Tumour outline shown in lateral view.

proved to be the case and it was impossible, quite often, even at operation, to decide whether one was dealing with a meningioma or neurofibroma unless the nerve filaments could be detected passing through the tumour. In fact five of the twenty-nine were extradural, but of these five, three could very reasonably be placed in a separate subgroup.

Thus there remain only two tumours which were of the ordinary extradural type and yet produced no roentgen changes. One lay between vertebrae on the right side of C. 2 and C. 3, passing between the adjacent laminae. Some laminal erosion was in fact seen at operation but even retrospectively could not be seen in the films. The other tumour was situated at the level of L. 1; though extradural, it lay entirely within the spinal canal.

The other 24 tumours, two of which were cervical and the remainder scattered throughout the thoracic and lumbar spinal canal, were intradural. Myelography was essential in this group. But often, having localised the tumour, it was impossible to differentiate it myelographically

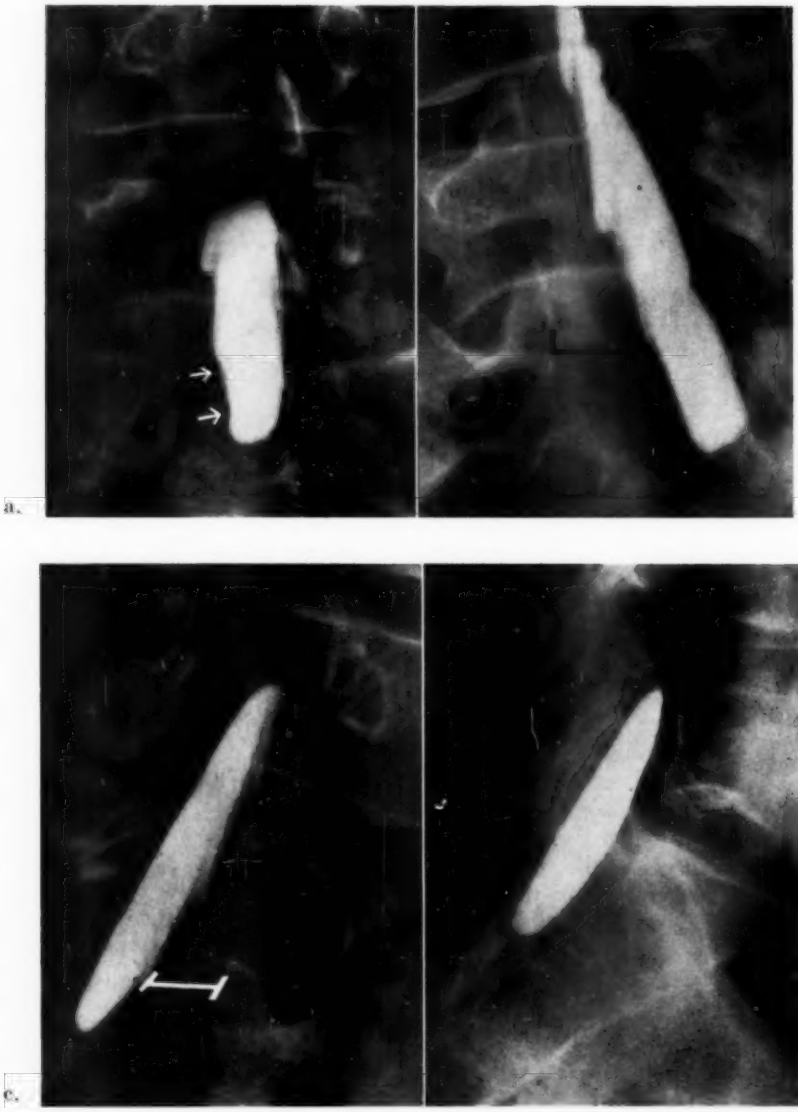


Fig. 14. (a) P. A. view. Filling defect on right just below lumbo-sacral junction. (b) Right oblique view showing subarachnoid space displaced away from pedicle. (c) Left oblique view showing normal relationship between subarachnoid space and pedicle. (d) Lateral view.

from a meningioma. Fig. 13 illustrates such a case. The ordinary films were normal and lumbar myelography showed a complete block at the lower end of the seventh thoracic vertebra. The spinal cord was seen displaced to the right (a) and the lower pole of the tumour was outlined on the left. The lateral view (b) showed the tumour to be lying in the posterior part of the spinal canal. A diagnosis of an intradural, extramedullary tumour lying posteriorly on the left side was made. It was quite impossible to state whether the tumour was a neurofibroma or meningioma, or indeed it could have been some rare tumour type situated intradurally and outside the medulla.

Finally we must return to the three other cases, all with normal findings, which fall into a rather special subgroup. Clinically all three simulated protruded lumbosacral discs. At myelography swollen nerve roots were shown and it was thought that a protruded disc was the cause. However, at operation no disc was found. In two cases there was a diffuse swelling of the fifth lumbar nerve and in the other a diffuse swelling of the first sacral nerve (Fig. 14 a, b, c, d) extradurally in each case. I do not think these cases can be differentiated radiologically from oedematous nerves pressed upon by protruded discs. No biopsies were carried out, for obvious reasons, but macroscopically the lesions were regarded as diffuse neurofibromata by McKissock who performed the operations.

Discussion

Considering the neurofibromas as a whole, one interesting point which is noticeable in the series is a complete absence of any tumour on the first cervical nerve, that which emerges between the occiput and atlas. A neurofibroma at this level would be unmistakable as the anatomical landmarks are so definite. By contrast, the second cervical nerve, that which emerges between the atlas and axis, was the most commonly affected of all.

It is tempting to try and compare the radiological findings of spinal neurofibromas with acoustic neuromas. About 80 % of the latter manifest themselves radiologically by the widening of the internal auditory meatus. In the other 20 %, the widening is either so slight as to be undetectable radiologically, the tumour is so small as not to cause meatal widening, or it lies up against the brain stem and not on the more peripheral part of the nerve.

As already described, the spinal neurofibromas have a greater variety of anatomical sites at which to be situated than acoustic tumours. Those that are intradural cannot usually be differentiated from meningiomas. The majority of intradural tumours produce gross neurological signs by

pressing the cord before causing pressure erosion on the bones. The other types of neurofibroma situated more peripherally along the nerve, can grow to a considerable size without necessarily damaging the cord, and yet during growth may cause quite gross bone destruction.

General Conclusions

1. Spinal meningiomas and neurofibromas occur about equally frequently and together represent over half of all intraspinal tumours.

2. They are nearly all benign and amenable to surgery though both types occasionally undergo malignant change. In the case of meningiomas the uncommon extradural group is more liable to become malignant.

3. Nearly all spinal meningiomas (85 % in this series) occur in women, while neurofibromas occur about equally frequently in the two sexes.

4. Meningiomas tend to occur in older subjects, but no age is immune to either type of tumour.

5. The distribution is quite different in the two tumour types. Neurofibromas are seen at any level of the spine except between the occiput and atlas. Meningiomas are nearly all situated in the thoracic region.

6. Meningiomas often calcify and sometimes ossify, but this sign is disappointingly seldom observed radiologically. Changes of any kind on roentgen examination, without contrast are rare.

On the other hand neurofibromas probably never calcify.

7. Intradural and extradural neurofibromas occur about equally frequently.

8. Intradural neurofibromas very seldom produce changes in ordinary roentgenograms.

Extradural neurofibromas nearly always produce changes in ordinary films and are very frequently of the dumbbell type.

9. If more than two adjacent vertebrae show radiological changes the tumour is not very likely to be a meningioma or neurofibroma.

10. Myelography is often necessary (a) to give the level and (b) the position relative to the cord, (c) to exclude an intramedullary lesion and differentiate an intradural from an extradural tumour, and (d) if the block to the contrast substance is incomplete it may be possible to delineate the whole of the tumour, or at least the upper and lower poles.

Acknowledgements

It is a pleasure to express my thanks to all my colleagues under whose care the patients were. Particularly I wish to thank Mr. Wylie McKissock who operated on the majority of the cases and drew my attention to the small special group of extradural lumbosacral neurofibromas as well as to Mr. Harvey Jackson and Mr. Valentine Logue, the surgeons who operated on the other cases.

SUMMARY

A material of fifty-nine cases of meningioma and fifty-two cases of neurofibroma of the spine is analysed. These two benign types represent over fifty per cent of spinal tumours. About half the neurofibromas were extradural and most of this type showed changes on ordinary roentgen examination. In the intradural neurofibromas or in the meningiomas, the majority of which were intradural, roentgen changes were seldom seen in ordinary films. Calcification or ossification, commonly found histologically in the meningiomas, is seldom visible radiologically in vivo. Myelography allows accurate localisation to be made when changes on ordinary films are lacking and also differentiates intradural from extradural tumours.

ZUSAMMENFASSUNG

Ein Material von 59 Meningeomen und 52 Neurofibromen des Rückenmarks wird analysiert. Diese beiden gutartigen Typen representieren mehr als 50 % aller Rückenmarktumoren. Etwa die Hälfte der Neurofibrome waren extradural gelegen und die Mehrzahl dieser Fälle zeigte bei der rutinmässigen Röntgenuntersuchung Veränderungen. Nur selten fand man Veränderungen bei intraduralen Neurofibromen und bei Meningeomen, die in der Mehrzahl der Fälle intradural gelegen waren. Verkalkungen oder Verknöcherungen, die man histologisch gewöhnlich bei den Meningeomen findet, sind röntgenologisch in vivo selten sichtbar. Die Myelographie erlaubt die genaue Lokalisation in Fällen, wo die rutinmässige Röntgenuntersuchung versagt; sie differentiert auch intradurale Tumoren von extraduralen Neubildungen.

RÉSUMÉ

L'auteur analyse une série de cinquante-neuf cas de méningiomes et de cinquante-deux cas de neurinomes spinaux. Ces deux types de tumeurs bénignes représentent plus de cinquante pour cent des tumeurs spinales. La moitié environ des neurinomes étaient extraduraux et la plupart de ceux-ci se manifestaient par des modifications des radiographies standard. Ces modifications étaient rares dans les neurinomes intraduraux et dans les méningiomes, dont la plupart étaient intraduraux. La calcification ou l'ossification, histologiquement fréquentes dans les méningiomes, sont rarement radio-visibles in vivo.

La myélographie permet une localisation exacte quand les radiographies standard sont normales, et permet aussi de distinguer les tumeurs intradurales des tumeurs extradurales.

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FROM THE ROENTGEN DEPARTMENT (DIRECTOR: PROFESSOR ERIK LINDGREN),
SERAFIMERLASARETTET, STOCKHOLM, SWEDEN

DIAGNOSIS OF SPINAL TUMOURS BY MEANS OF GAS MYELOGRAPHY

by

Sven Odén

Myelography may be carried out with positive or negative contrast. The positive contrast media are of two types: 1) iodized oils, such as Lipiodol, Jodipin, Immetal and Pantopaque, 2) water-soluble contrast media of the Abrodil type (Skiodan). The former may be used for examinations of the entire vertebral canal, while the latter are only applicable to the lumbar region. That is to say, because of their highly irritating effect upon the membranes in the dural sac, the water-soluble contrast media cannot be injected without previous anaesthesia.

Lipiodol and Pantopaque are the preparations most generally used in myelography. These have certain advantages. The contrast has great density. As a rule, the radiographs permit therefore of a diagnosis even if their technical quality is inferior, and usually the patient is subjected to less strain by the examination.

However, in our opinion, the disadvantages in the use of iodized oils are considerably greater than the advantages. Some patients are hypersensitive to iodine and thus cannot be examined with a positive contrast medium. Furthermore iodized oil is not absorbed. Consequently the contrast medium must be removed from the subarachnoidal space after the examination. This may be done by means of lumbar puncture or a burr hole made in the sacrum, or by opening the dura in conjunction with operation. Frequently, however, despite all efforts, some amount of contrast medium remains in the subarachnoidal space and may later give rise to granuloma formation in the membranes. Whether or not these anatomic changes produce clinical symptoms is disputed. On the other hand, if an operation is not carried out immediately, for some reason, but is performed instead several weeks later, the iodized oil may cause adhesions around a tumour, making its radical removal more difficult and sometimes impossible.

From a purely radiological point of view also, iodized oil has certain disadvantages. Any residual contrast medium renders a renewed examination harder or impracticable. Small changes may be hidden due to excessive contrast density. Moreover, the oil sometimes disintegrates into droplets, complicating the examination. Therefore, in 1944 when RAMSEY, FRENCH and STRAIN published their results with the then new Pantopaque, which, through its lower viscosity had less tendency to drop formation, was easier to remove from the subarachnoidal space and had little or no irritating effect upon the arachnoid membrane, it appeared that the ideal contrast medium had been found. This was particularly so since Pantopaque was also said to be absorbed from the subarachnoidal space. Subsequent investigations concerning the absorption of Pantopaque, however, showed that this takes place very slowly. The rate in man has been stated to be 1 cc per year. Experiments have also been carried out at Serafimerlasarettet with the injection of Pantopaque in dogs, demonstrating that Pantopaque remained, fixed in granulomas along the entire subarachnoidal space at control examinations a few months later. It was also pointed out by many investigators that Pantopaque had the same irritating effect upon the arachnoid membrane as Lipiodol. Pantopaque, nevertheless, soon became the medium of choice in America and many countries in Europe.

Myelography with air was suggested by DANDY in 1919. In the beginning only small quantities were used for the diagnosis of complete block. The method was unreliable, however, partly due to the difficulty in producing good radiographs with the technical equipment then available. Therefore, when SICARD and FORESTIER introduced Lipiodol in 1922, it became the most widely accepted medium.

In 1938, gas myelography received an impetus through the work of YOUNG and SCOTT, who introduced the new principle of complete air filling of the lumbar portion of the spinal canal. They also suggested that the entire spinal canal might be examined by injecting 65—85 cc of air by means of cisternal puncture, but did not develop this idea in detail. However, during 1938 and 1939, the new principle was amplified by LINDGREN to include emptying of the entire subarachnoidal space of fluid and replacing the latter with air under pressure, so that the subarachnoidal space was distended as far as possible out to the walls of the vertebral canal, all the way up to the base of the skull. Without sufficient distension of the subarachnoidal space, extradural lesions of small dimensions in the vertebral canal cannot be diagnosed.

The advantages of using gas are numerous. The method is not dangerous. Hypersensitivity to gas is non-existent. No toxic after-effects upon the membranes, in the form of arachnitis with residual adhesions and granuloma formation, have been observed. The gas is absorbed and

leaves no traces. Examinations may thus be repeated if necessary and myelography may be performed upon less restricted indications than with a positive contrast medium. Fluoroscopy is unnecessary. The radiographs may be studied by many examiners and it is not necessary to depend upon the report of the fluoroscopist.

The disadvantages of the method are that it is more time-consuming than the iodized oil method, being therefore more exacting for the patient who must lie with his head lowered. Thus, with older patients, the indications for gas myelography should be more limited. There is also a greater need for technically good radiographs. To approximately the same degree, both positive contrast media and gas cause a slight increase in the protein and cells in the cerebrospinal fluid, as well as a slight rise in temperature in connection with the injection. The subjective symptoms, such as headache and nausea, on the other hand, are somewhat more pronounced with gas.

Technique

The patient is placed in the lateral position on a tilting couch and secured by a harness around the shoulders which is attached by a shackle at the foot of the couch. The foot of the couch is then raised to an angle of 15—25 degrees. The patient's head rests on a low pillow, not high enough to allow air to pass up into the skull. With the patient in this position, cisternal puncture is made and the fluid replaced successively with oxygen at body temperature, until all fluid has been withdrawn from the subarachnoidal space. Early in the history of this method at Serafimerlasarettet, oxygen was used in place of air, since oxygen is absorbed considerably more rapidly than air. By means of an apparatus constructed here, the oxygen is also warmed to body temperature and humidified, thereby decreasing to a great degree, the subjective discomfort of the patient. Furthermore, a suitable pressure can more easily be obtained with this apparatus than with an ordinary syringe. The pressure is measured with a manometer and should reach approximately 250 to 300 mm water. After the gas injection is completed the needle is withdrawn and the roentgen examination is begun. (Fig. 1.) Radiographs of the entire subarachnoidal space are taken with the patient still in the lateral position. This affords a general conception of the gas distribution in the subarachnoidal space, the occurrence of possible obstructions, etc. If changes requiring further investigation are observed on these preliminary films, views in suitable projections are taken until the condition is fully clarified. In addition, we use tomography regularly in the investigation of the thoraco-cervical junction, since the bones of the shoulders and the thick musculature usually complicate the production

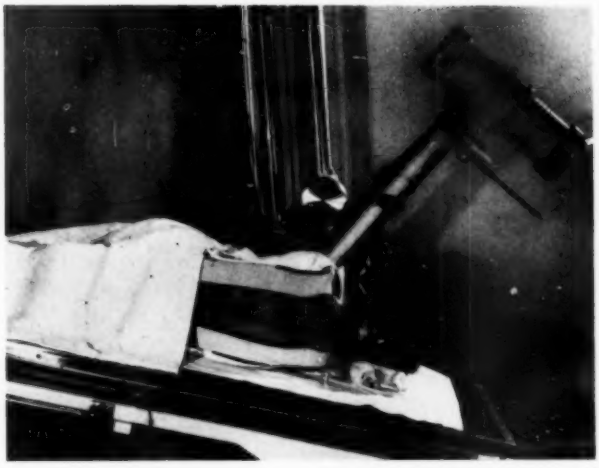


Fig. 1. The patient ready for the roentgen examination. The tube is tilted for a tomographic film of the thoraco-cervical junction.

of a technically good conventional radiograph. Tomography is also used on the parts where a change is suspected, but cannot be routinely used on the entire vertebral canal as the radiation dose would be excessive.

In the literature, 60 cc of gas is generally said to be sufficient. However, according to our experience, at least twice this quantity is necessary in the examination of an adult when there is no blocking off of the subarachnoidal space if this space is to be visualised well distended. (Fig. 2.) With a smaller quantity of gas there is a risk of obtaining a fluid level in the upper part of the thoracic spinal canal, and this may incorrectly be interpreted as a block in the subarachnoidal space. Nor is it possible, as a rule, to examine the cervical part of the subarachnoidal space with too little gas.

We usually perform the examination through cisternal puncture. In the position in which the patient lies for this examination, the subarachnoidal space forms a closed sac, directed upward, and by puncture of the bottom of this sac, conditions are favourable for complete emptying of the fluid. If a total block has been demonstrated at this examination and a conception of the extent of the obstruction in the vertebral canal is desired, a new examination is performed by lumbar puncture, thus establishing the lower limit of the obstruction.

If the objective is examination of the lumbar and thoracic vertebral canal only, this may also be carried out by lumbar puncture. The fluid

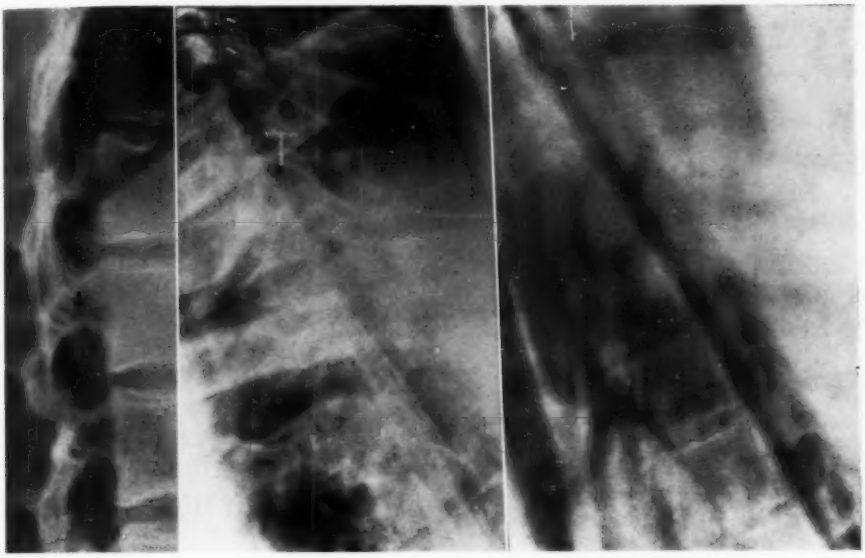


Fig. 2. Fig. 3 a. 3 b.

Fig. 2. The value of a complete gas filling of the subarachnoidal space is demonstrated in this picture. Both the superior and inferior poles of a neuroma at the level of Th XII is clearly visible. Gas filling by cisternal puncture only. (Confirmed by operation.)

Fig. 3. The thoraco-cervical junction in a normal case. Very muscular patient. a) Conventional film, b) tomographic.

is then withdrawn with the patient in a horizontal position. After about 50—60 cc are withdrawn, the foot of the couch is raised, as for cisternal puncture, and the oxygen injected. It is then possible to use a higher pressure (up to 500 mm H_2O) than with cisternal puncture and, as a rule, the lumbar as well as the thoracic subarachnoidal space is gas-filled. The cervical part, on the other hand, cannot be examined by this method.

If the clinical examinations such as double puncture and Queckenstedt's test, have given clear indications of a complete block in the subarachnoidal space, it is possible to spare older patients by using only a small quantity of gas (20 to 30 cc) injected by lumbar puncture to localise the lower limit of the obstruction.

Since 1938 more than 2,100 gas myelographies have been performed at Serafimerlasarettet. The results, taken from a five year period from 1947 to 1951, will be presented here. During this period the technique has been fully developed and uniform. More than 800 examinations have

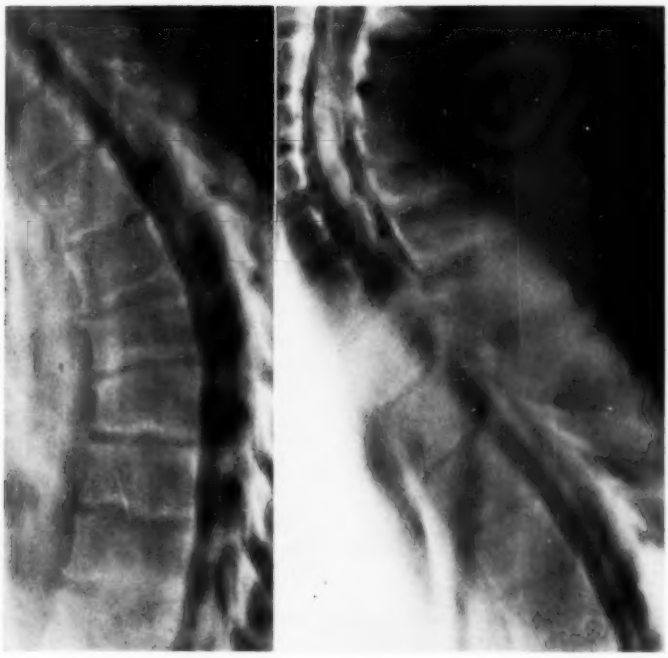


Fig. 4. The medulla is abnormally thick in the cervical region, extremely thin and irregular in the thoracic. Clinical diagnosis: Syringo-myelitis.

been carried out. Of these, all cases with positive radiographic findings have been studied, with the exception of cases of herniated disc in the cervical or lumbar regions. In addition I have reviewed all cases of spinal changes treated operatively in the Neuro-surgical Department of Serafimerlasarettet, in order to discover cases in which changes were found at operation but overlooked at the roentgen examination. In seven cases with positive radiographic findings it was impossible to locate the records of the patients, thus precluding verification of the radiographic diagnosis.

The material obtained, comprises 115 cases, all verified by operation or autopsy. The changes in these cases, in relation to the membrane of the vertebral canal were situated as follows: intramedullar 24, extramedullar 88. Of the latter 59 were intradural (juxtamedullar) and 29 were extradural. In addition, the material includes one meningocele and two cases of kyphotic myelopathy. The youngest patient examined was

Fig. 5.

Fig. 6.

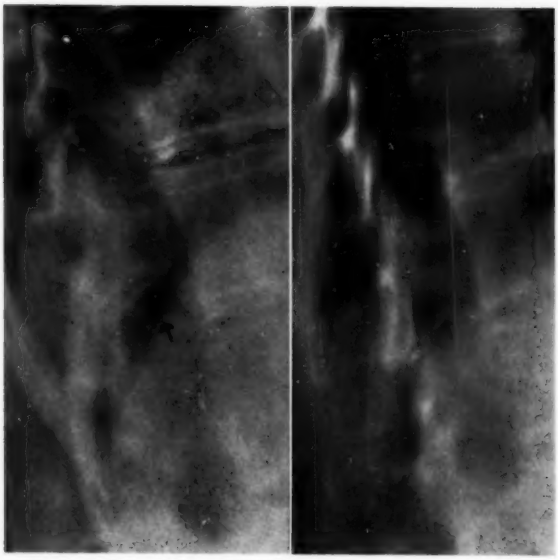
Fig. 5. Intramedullary tumour (glioma) causing a complete block at the level of C V.
Fig. 6. Intramedullary tumour (ependymoma) between Th VI and Th IX, causing a relative block.

a seven-year-old boy with an astrocytoma, and the oldest an eighty-year-old woman with a meningioma.

The most important objective of myelography, in our opinion, is to demonstrate a possible spinal change, tumour or other type, and to establish the level at which it is situated. Its more detailed site, extradural, juxtamedullar or intramedullar, is of less importance from the practical medical viewpoint.

It was possible to establish an exact level in 109 of the 115 cases, that is to say in 94.8 per cent. The radiologic and operative findings did not agree in six cases. Before proceeding with a comparison of our figures with those of other series, I shall discuss these six cases in greater detail and attempt to explain the causes of the discrepancies between the radiologic and operative findings.

In principle, incorrect radiologic diagnosis may depend upon two factors, the human and the methodic. By the human factor I mean that



a. b.

c.

d.

Fig. 7. Juxta-medullary tumour (neurofibroma) causing a complete block at the level of Th XII—L I. a) Conventional film. b) and c) Tomographic films. d) Diagram of 7 c). The medulla is pressed forward and sharply curved to the left immediately above the tumour.

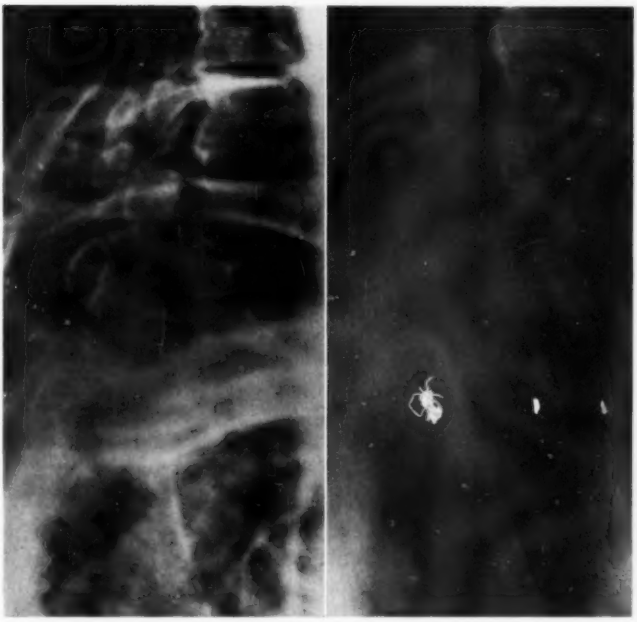


Fig. 8. Conventional film to the left, tomographic to the right. In the latter a destruction is seen in the 2nd and 3rd thoracic vertebrae and there is no gas filling of the subarachnoidal space at this level. The medulla appears to be normal above and below this level. (Six years ago op. for a prostatic carcinoma. Now symptoms of a medullary lesion.)

the radiologist overlooks or misinterprets a change and that the operative diagnosis is verified through subsequent study of the radiographs. Also to be included among the human factors, in my opinion, are the possible errors resulting from insufficiently thorough examination — that is when the examiner has not exploited the possibilities afforded by the method.

The methodic factor includes the errors which depend upon changes observed in the vertebral canal at operation, which could not be observed either by the radiologist at the time of his examination or at a later study of the radiographs, in spite of a technically satisfactory examination.

Of the six incorrect diagnoses, four may be attributed to the human factor. In the first case a meningioma at the level of the 7th thoracic vertebra had been overlooked. In the second, an extradural malignant tumour on the posterior side of the dura at the level of the 5th, 6th and

7th thoracic vertebrae was missed. In the third, a herniated disc between the 7th and 8th thoracic vertebrae was found at operation and could be observed in the radiographs on later study. In the fourth case the results of the radiologic examination were partially correct. That is to say, a relative obstruction of the passage was observed at the level of the inferior border of the 12th thoracic, and at operation the dural sac was found to be blocked at that site by arachnoid adhesions. However, laminectomy on the 6th and 7th cervical vertebrae was also performed, and revealed the presence of numerous small tumours originating from both the posterior and anterior roots on both sides. It was a typical picture of multiple neurofibromas. Later study of the radiographs showed that the subarachnoidal space of the cervical spinal canal had not been adequately examined.

Of the two remaining cases, those which could not be attributed to the human factor, one exhibited a syringomyelitic cavity at the level of the fifth, sixth and seventh cervical vertebrae at operation. According to the surgeon, this completely filled the vertebral canal. The radiographic examination revealed a kyphosis in the inferior part of the cervical spine and an anterior inward bulging of soft tissues in the subarachnoidal space at the level of the disc between the sixth and seventh cervical vertebrae. There was an obvious layer of air, however, in the anterior subarachnoidal space between the posterior borders of the vertebral bodies and the medulla. In this case the discrepancy seems to have been dependent upon the increase in size of the cavity between the time of the radiologic examination and the operation seven weeks later, or upon a misconception on the part of the surgeon due to the patient's position at operation: that is to say, that the patient's neck was flexed forward so that the surgeon obtained a false impression that the medulla completely filled the vertebral canal.

At operation, in the sixth and final case, an intramedullar tumour, smaller than a hazel nut, was found at the level of the eighth thoracic vertebra, causing only a very slight expansion of the medulla, principally on the left side. No changes were observed at the radiologic examination, nor were any found on later study of the radiographs. In this case, myelography with Pantopaque was also performed, but again no changes at the affected level were observed. The signs were, therefore, too slight to be demonstrated radiologically.

In conclusion, it may thus be said that the majority of the errors in these six cases depended upon the examiner, a source of error inherent in all investigations whether radiologic or otherwise.

The pathologic changes in three cases were localised to the middle part of the thoracic vertebral canal and in one case to the lowest part of the cervical. With regard to the type of the changes, we find that in

three cases they were extradural and in one case juxtamedullar, indicating that small extradural lesions are easier to overlook.

No extensive or reliable series of gas myelographies in cases of tumour are presented in the literature. When, in 1939, LINDGREN began to develop our present technique, he was of the opinion, based upon a material of 14 tumours of which 13 were precisely diagnosed with gas myelography, that gas was practically as reliable as Lipiodol in the diagnosis of juxtamedullar and intramedullar tumours. On the basis of the material I have reviewed, it appears that this contention can be amplified: that is, that gas myelography is just as dependable as Lipiodol in the diagnosis of expanding lesions in the spinal canal.

Among the collocations of myelographies with positive contrast media, CAMP, in 1938, presented a material comprising 198 cases of verified tumours. In 72 of these cases the diagnosis was based on Lipiodol myelography: in one the diagnosis was incorrect, a reliability of 98.6 %. The following year, together with ADDINGTON, he published a myelography material comprising 417 cases, including 45 tumours upon which 43 were operated. In two cases the findings were negative at operation. This represents a reliability of 95.3 %.

In 1949, HANNAN, HUGHES and MULVEY presented a material of 68 patients with spinal cord tumours. Pantopaque myelography was carried out in 40 cases, with exact diagnosis in 38, thus giving a 95 per cent reliability.

A recapitulation of all materials shows accordingly that myelography, regardless of the method, has a reliability of approximately 95 per cent. The series published earlier have limited statistical value, however, inasmuch as the ratio of relative to complete block is not given. Diagnosis of complete block is always possible by any method, but that of relative block is more difficult, thus proving the value of a method. In our material the pathologic changes caused no block, or only a relative obstruction of the oxygen passage, in as many as 51 out of 115 cases, *i. e.* about 45 per cent.

It is not evident from the earlier series whether or not patients with negative myelographic diagnoses later underwent operation and then exhibited changes in the vertebral canal.

In the Neuro-surgical Department at Serafimerlasarettet, however, there is a follow-up system by which patients are re-admitted for renewed examination if their symptoms increase in severity. For this reason, our negative findings may be considered reliable.

It is evident from our material that more detailed localisation of tumours, as intra- or extramedullar, is somewhat more difficult with gas than with positive contrast media. Such localisation could be made definitely in only 30 cases, and these were principally the intradural

juxtamedullar. In order further to improve the diagnostic methods and especially to see if more detailed localisation in relation to the dura could be obtained, as well as to facilitate examination of the thoracocervical junction, we have systematically employed tomography for approximately six months with very encouraging results. The material is still too limited for statistical treatment, however, but the examples shown in the figures will perhaps give an idea of its advantages.

SUMMARY

After a short discussion concerning the advantages and disadvantages in the use of positive and negative contrast media for myelography and after a short description of the present technique for gas myelography at Serafimerlasarettet, Stockholm, the author gives an account of the results from about 800 gas myelographies, containing 115 cases with positive findings. An exact diagnosis was obtained in 95 per cent of the cases. Finally the author points out the value of tomography in gas myelography and this is illustrated with films, taken both with this and with the ordinary technique.

ZUSAMMENFASSUNG

Nach kurzer Besprechung der Vor- und Nachteile von positiven und negativen Kontrastmitteln bei der Myelographie und nach kurzer Beschreibung der gegenwärtigen Technik, die für Gasmyelographien am Serafimerlazarett in Stockholm angewendet wird, gibt der Verf. einen Bericht über 800 Gasmyelographien, darunter 115 Fälle mit positivem Befund, ab. In 95 % der Fälle konnte die Diagnose exakt gestellt werden. Zum Schluss hebt der Verf. den Wert der Tomographie bei der Gasmyelographie hervor; der Wert wird mit Röntgenaufnahmen illustriert, die sowohl mit dieser letztgenannten als auch mit der üblichen Technik hergestellt worden sind.

RÉSUMÉ

Après avoir brièvement discuté les avantages et les inconvénients de l'emploi des moyens de contraste positif et négatif pour la myélographie et après une brève description de la technique actuellement employée à Serafimerlasarettet, Stockholm, pour la myélographie gazeuse, l'auteur rend compte des résultats d'environ 800 myélographies gazeuses dont 115 ont donné des résultats positifs. Le diagnostic exact a été posé dans 95 pour cent des cas.

L'auteur insiste enfin sur l'intérêt de la tomographie dans la myélographie gazeuse et en donne des exemples à l'aide de films pris avec et sans tomographie.

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DU SERVICE CENTRAL D'ÉLECTRO-RADIOLOGIE, HÔPITAL DES ENFANTS MALADES, PARIS, FRANCE

ÉVOLUTION DES SIGNES RADIOGRAPHIQUES DES ATROPHIES CÉRÉBRALES UNILATÉRALES

par

J. Lefebvre, E. Guy et *J. Metzger*

Les signes osseux de l'atrophie cérébrale unilatérale ont été décrits anatomiquement par H. COTTARD, élève de CHARCOT, dans sa thèse inaugurale.

Ce n'est qu'en 1933 que DAVIDOFF, DYKE et MASSON ont montré la traduction radiographique de ces signes et qu'ils ont insisté sur l'affaissement et l'épaississement de la demi-voûte, sur l'expansion unilatérale du système sinusal, particulièrement frontal et ethmoïdal, dont les parois bombent vers l'intérieur du crâne, sur une soufflure du bord supérieur du rocher, le tout traduisant une diminution de la capacité de l'hémicrâne atrophié.

En 1944, CHILDE et PENFIELD, en 1948 MAC RAY ont précisé ces signes chez le grand enfant et chez l'adulte.

Mais CAFFEY écrivait en 1950 «Such changes do not develop in infants».

Nous devons à FISCHGOLD d'avoir eu l'attention attirée sur la précocité d'apparition des signes osseux. En 1950, avec PETIT-DUTAILLIS, il ajoute à la symptomatologie le rétrécissement de la fosse temporo-sphénoïdale, avec épaississement de la grande aile; en 1951, il décrit avec l'un de nous l'obliquité du jugum, liée à une surélévation du massif ethmoïdo-sphénoïdal du côté atrophié, la pneumatisation de l'apophyse clinoïde antérieure, l'emboîtement de la table interne du côté atrophié, qui se dessine sur l'image de profil à l'intérieur de la table interne de l'hémicrâne sain, enfin un signe précoce: la latéralisation apparente de la fontanelle antérieure.

Dans une récente communication à la Société Française de Pédiatrie, nous avons décrit un signe précoce qui nous paraît trés constant: l'aspect remarquablement lisse de la table interne densifiée, tel qu'on peut parler

d'une absence des impressions digitiformes. Nous avons par ailleurs constaté que l'élévation du jugum s'accompagne d'une élévation de la petite aile du sphénoïde et d'un élargissement de celle-ci.

Notre étude portait alors sur 64 observations d'hémiplégie cérébrale infantile; nous l'avons depuis complété par 40 observations d'atrophie cérébrale unilatérale, relevant des causes les plus diverses.

Nous nous proposons, après un bref rappel de l'étiologie de l'atrophie cérébrale unilatérale et de la technique radiologique qu'impose sa recherche, de situer les dates d'apparition des signes radiologiques osseux. Nous insisterons sur la rapidité d'installation de ces signes, sur leur précocité, sur leur localisation possible. Enfin, nous terminerons par une comparaison entre les renseignements fournis par la radiologie simple et ceux que donnent les autres méthodes d'investigation neuro-radiologique.

Étiologie des atrophies cérébrales unilatérales

Les causes des atrophies cérébrales unilatérales sont pour la plupart néonatales:

accouchement dystocique ayant nécessité un forceps, circulaire du cordon, prématuré, anoxhémie, déchirure dure-mérienne;

angiomatose, syndrome de STURGE-WEBER (angiomatose encéphalo-trigéminée); l'un de nous en ayant étudié 7 cas à l'occasion de sa thèse y a retrové la plupart des signes osseux d'atrophie cérébrale unilatérale;

toxoplasmose lorsque l'infection prédomine d'un côté et ne s'accompagne que d'une hydrocéphalie modérée.

L'atrophie cérébrale unilatérale avec signes osseux peut, mais rarement, se constituer à la suite d'une atteinte cérébrale survenue au cours de la première ou même de la seconde enfance:

d'une encéphalite, d'une oto-mastoïdite,
ou d'un traumatisme cranien.

Technique radiologique

L'étude de l'atrophie cérébrale unilatérale reposant sur une comparaison entre le deux hémicrânes, les clichés de profil donnent peu de renseignements, mis à part le signe de l'emboîtement et la soufflure d'un toit orbitaire qui apparaît convexe et bombé à l'intérieur du crâne.

Les clichés de face permettent de rechercher tous les autres signes, certains d'entre eux nécessitant une radiographie strictement de face. En effet, la symétrie normale du crâne peut être faussée par une incidence légèrement oblique. Les asymétries, lorsqu'elles sont nettes, ne sont pas

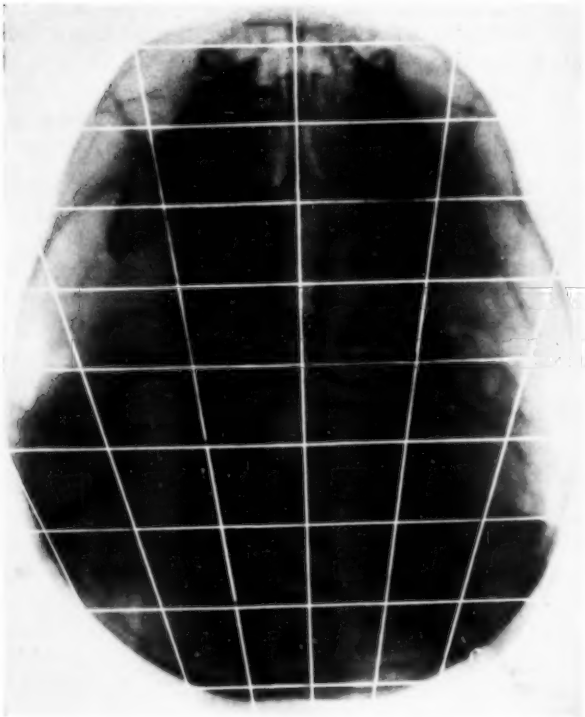


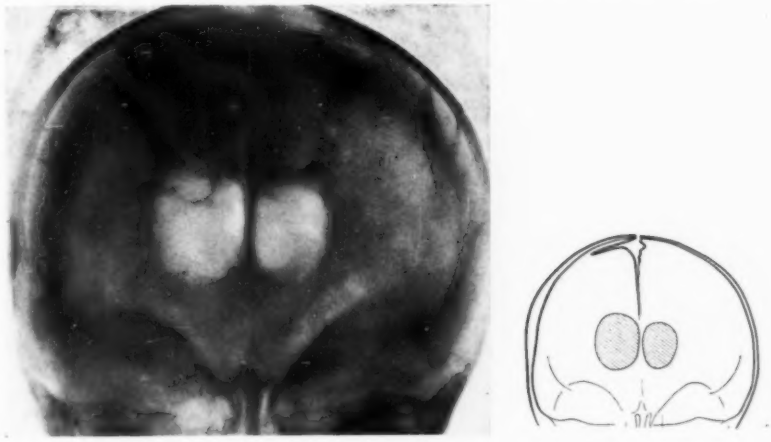
Fig. 1. Quadrille trapézoidal pour l'étude de l'asymétrie. L'incidence axiale met en évidence (grâce au calque) des signes discrets d'atrophie, au niveau de l'étage moyen, à gauche.

(R . . . Monique, 20 mois; accouchement: rien à signaler; de 1 mois à 9 mois: otites à répétition; hémiplégie droite à 10 mois.)

sujettes à discussion. Dans certains cas, par contre, il est utile d'employer un des procédés suivants:

a. On peut prendre du cliché de face un calque qui, plié selon l'axe, renseigne immédiatement sur l'asymétrie. Cet axe, projection du plan sagittal de part et d'autre duquel se répartissent les deux hémisphères, est donné par la suture médiane, la gouttière du sinus longitudinal supérieur ou la fontanelle, le nasion et la tubérosité occipitale externe (ou, à son défaut, l'apophyse odontoïde de l'axis).

b. On peut utiliser un calque quadrillé trapézoïdal sur lequel on examine la radiographie en superposant l'axe du calque et l'axe du crâne (Fig. 1).



a. b.

Fig. 2. Epaississement du diploë à droite. Latéralisation apparente de la fontanelle.
(V . . . N. 4 mois; forceps; crises convulsives; paralysie faciale gauche.)

L'incidence de face la plus intéressante est celle qui permet d'obtenir les fentes sphénoïdales.

L'incidence fronto-sous-occipitale est souvent instructive, ainsi que l'incidence axiale.

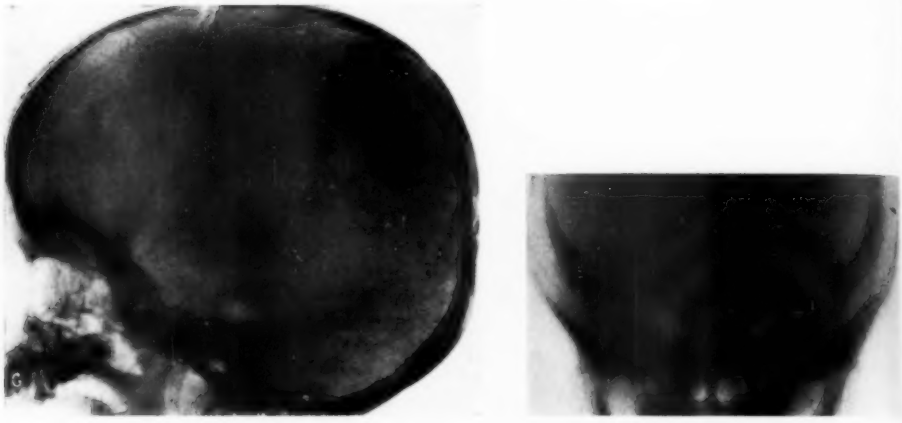
Développement des signes osseux de l'atrophie cérébrale unilatérale

L'atrophie d'un hémisphère s'accompagne d'une sorte de contraction de l'hémicrâne. Tout se passe comme si la pression exercée par le cerveau, plus faible, ne repoussait pas la table interne autant que du côté sain. Il en résulte un épaississement du diploë et, là où cela est possible, une expansion des cavités pneumatiques.

Les cavités pneumatiques para-nasales apparaissent radiologiquement à partir de la deuxième année. Madame SILBERMANN, dans sa thèse, a rappelé les chiffres suivants:

cellules ethmoïdales ..... entre 1 et 2 ans,
cellules mastoïdiennes ..... entre 1 et 3 ans,
sinus sphénoïdal ..... entre 1 et 3 ans,
sinus frontaux ..... entre 4 et 6 ans.

L'atrophie cérébrale unilatérale se manifeste donc au cours des deux premières années par des signes purement osseux et en particulier par



a. b.

Fig. 3. Signe de l'emboîtement. Epaississement de la base du crâne à gauche. a. Radiographie ordinaire. b. Tomographie.
(Même cas que Fig. 1.)

une asymétrie globale du crâne. Celle-ci se traduit d'abord à la voûte, puis à la base (Fig. 2). C'est ainsi que, *au cours des premiers mois*, nous avons pu constater un affaissement de la voûte entraînant une asymétrie globale, l'épaississement du diploë, la latéralisation apparente de la fontanelle.

A la fin de la première année, à ces signes de la voûte s'ajoutent l'inclinaison du jugum, l'élargissement et la surélévation de la petite aile, le rétrécissement de la fosse temporo-sphénoïdale, la surélévation du rocher. C'est aussi à ce moment qu'on note l'aspect lisse de la table interne (Fig. 3).

A deux ans, apparaît l'inclinaison de l'apophyse crista-galli.

A partir d'un an et demi et au-delà, la fontanelle est comblée et c'est la suture médiane et la gouttière du sinus longitudinal qui apparaissent latéralisées (Fig. 4). Le signe de l'emboîtement traduit sur le profil l'asymétrie des deux hémicrânes. Les signes que nous avons vus plus haut sont exagérés: on a pu ainsi observer à neuf ans un dédoublement de la voûte orbitaire, à quatorze ans un aspect plus transparent du diploë (Fig. 5). Mais surtout, le développement prématuré et exagéré du système sinusal fait apparaître des signes dont l'évidence attire l'attention:

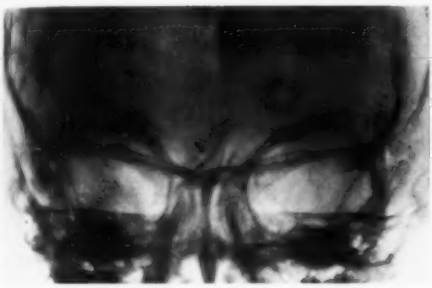


Fig. 4. Soulèvement de la petite aile et du jugum. Elargissement de la petite aile. Crista galli inclinée vers le côté gauche atrophié.

(L... Thérèse, 5 ans; encéphalite à 13 mois; crise convulsive, avec hémiplégie droite.)

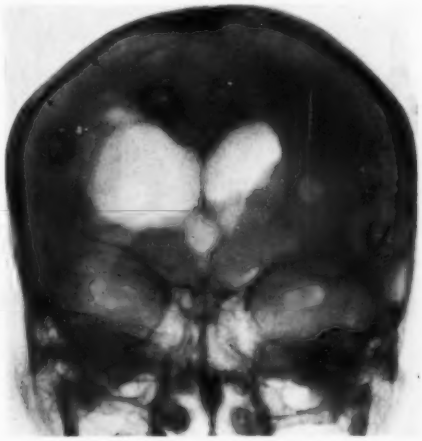
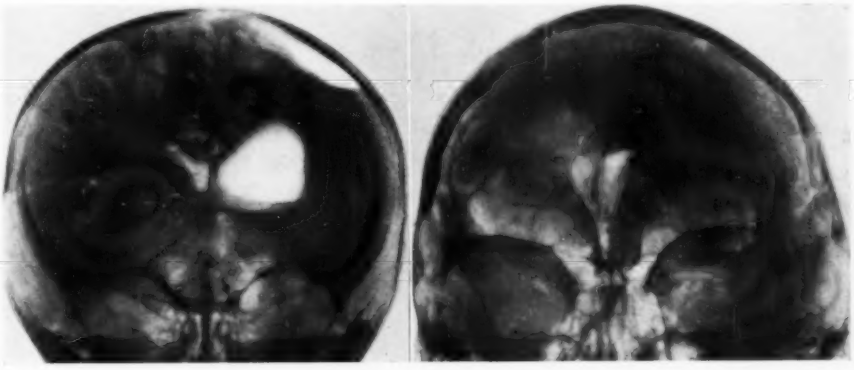


Fig. 5. Voûte affaissée, diploë plus clair, correspondant à la zone de dilatation ventriculaire, maxima à droite. Surélévation du rocher, à droite. Hyperpneumatisation des cellules mastoïdiennes.

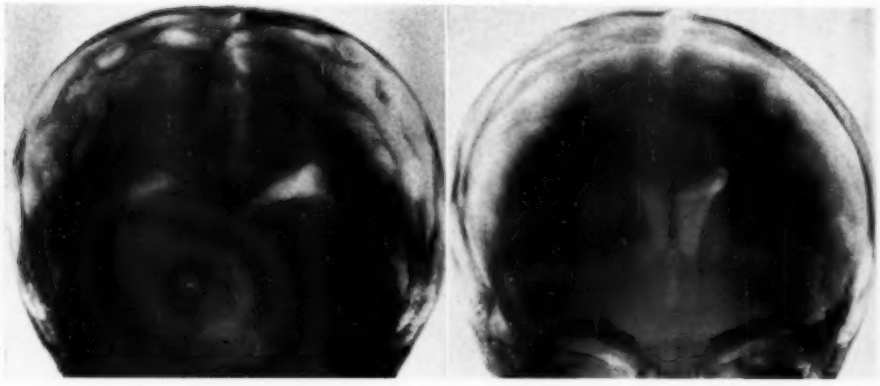
(Le D... Michel, 14 ans; réanimation pendant 1/2 heure après l'accouchement; hémiplégie gauche; crises convulsives.)



a. b.

Fig. 6. a. Apparition d'un recessus ethmoïdal sus-orbitaire gauche. Epaississement diploïque. Table interne plus lisse à gauche. (Même cas que fig. 1.)

b. Recessus ethmoïdal sus-orbitaire très développé à droite. Grosse dilatation ventriculaire droite. Refoulement à droite du système ventriculaire. (Même cas que fig. 5.)



a. b.

Fig. 7. Signe d'atrophie localisée. a. Incidence ne permettant de voir aucun épaississement localisé de la voûte. b. Incidence montrant un épaississement localisé de la voûte, du côté gauche.

(B . . . 2 ans; forceps; à 2 mois: crises convulsives, avec localisation du membre supérieur droit; paralysie du membre supérieur droit.)

à deux ans . . développement exagéré des cellules ethmoïdales, recessus orbitaire (Fig. 6),

à trois ans . . pneumatisation exagérée des cellules mastoïdiennes,

à cinq ans . . pneumatisation et asymétrie du sinus sphénoïdal,

à treize ans . . pneumatisation et asymétrie du système ptérygoïdien.

Sur nos 104 observations, nous n'avons noté dans aucun cas la pneumatisation de la clinoïde antérieure décrite par FISCHGOLD, nous n'avons vu que trois fois l'aspect transparent du diploë.

Rapidité d'installation des signes osseux

Les signes osseux d'atrophie cérébrale unilatérale peuvent s'installer rapidement dès le début de l'atteinte cérébrale. En voici un exemple entre plusieurs autres: un enfant, normal jusqu'à trois ans, présente une encéphalite, avec hyperpyrexie et crises bravais-jacksonniennes droites. Des radiographies, pratiquées un an plus tard (l'enfant étant agé de quatre ans), ont montré:

une asymétrie globale du crâne, une inclination de l'apophyse crista-galli,
un épaississement du diploë, une surélévation du rocher.

Précocité des signes osseux d'atrophie cérébrale unilatérale, qui peuvent précéder les manifestations cliniques

Quelques observations nous permettent de dire que les signes osseux de l'atrophie cérébrale unilatérale peuvent précéder les signes cliniques.

Fig. 8. Atrophie bilatérale à prédominance gauche. A gauche: Pneumatisation de la région ptérygoïdienne; recessus ethmoïdal sus-orbitaire; à droite: Dédoublement de la voûte orbitaire; nombreux autres signes à prédominance gauche.
(W... Guy, 12 ans; forceps; né cyanosé; première crise convulsive à 15 mois; hémiplégie droite; arriération mentale.)

A titre d'exemple: un enfant présente une crise d'épilepsie. Une radiographie du crâne, pratiquée quelques jours plus tard, montre des signes d'atrophie cérébrale. Nous en concluons que les signes osseux n'ayant pas pu s'installer en quelques jours se sont développés à bas bruit en même temps que l'atrophie du cerveau, jusqu'au jour où celle-ci s'est manifestée par une crise d'épilepsie.

Signes osseux localisés d'atrophie cérébrale

Dans quelques cas, les radiographes nous ont permis de localiser l'atrophie dans la région pariétale, temporale ou occipitale (les signes osseux concordant de façon parfaite avec les signes cliniques, encéphalographiques et électroencéphalographiques).

a. b.

Fig. 9. Atrophie bilatérale à prédominance gauche. a. Tomographie frontale destinée à montrer: l'épaississement, l'applatissement considérable du fond des fosses temporo-sphénoïdales, prédominant à gauche; le développement asymétrique du sinus sphénoïdal; la racine de la ptérygoïde plus large à gauche qu'à droite. b. Tomographie sagittale passant par le milieu de l'orbite droite montrant le dédoublement orbitaire qui atteint toute la voûte de l'orbite, la fosse temporo-sphénoïdale applatie. (Même cas que fig. 8.)

Il nous est possible aussi de suspecter par les radiographies simples des atrophies cérébrales généralisées, avec prédominance d'un côté (Fig. 7, 8, 9).

Encéphalographie et atrophie cérébrale unilatérale

L'importance des signes osseux est en général proportionnelle à l'importance de la dilatation et de l'asymétrie du système ventriculaire, ainsi que l'avait déjà vu DYKE en 1933.

L'encéphalographie met en évidence le déplacement du plan cérébral médian, dont l'image, non seulement se superpose à celle de l'axe cranien (latéralisation apparente de la fontanelle ou de la suture inter-pariétale et inclinaison de l'apophyse crista-galli), mais le déborde et s'incurve du côté atrophié.

Dans certains cas, l'air ne passe pas à la convexité du côté atrophié; ce fait avait déjà été vu par DYKE; dans d'autres cas, il existe un véritable lac liquidien sous-dural, mis en évidence par les incidences en rayon horizontal.

Parfois, l'aspect presque normal du système ventriculaire contraste avec l'importance des signes osseux de la voûte; ceci a été surtout observé dans les syndromes de STURGE-WEBER.

Nous avons noté l'existence de signes osseux localisés d'atrophie cérébrale dans la zône la plus proche d'une porencéphalie communicante ou d'une dilatation ventriculaire localisée. Il arrive dans ce cas que la table interne ait à ce niveau un aspect flou, mal limité.

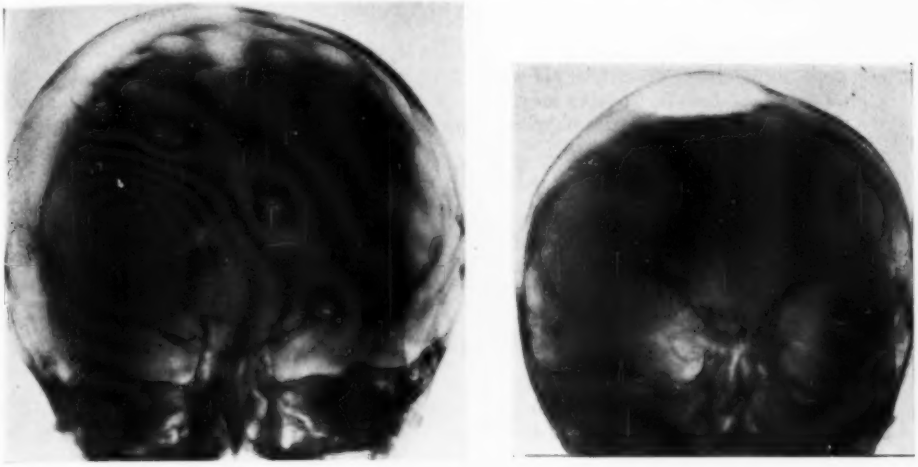
Diagnostic différentiel

1. *Asymétrie physiologique:*

Les deux hémicrânes des sujets normaux ne sont pas toujours strictement symétriques. En fait, sur plusieurs centaines de crânes d'enfants normaux, nous n'avons pas constaté d'asymétrie notable. Nous ne tiendrons pas compte des asymétries qui ne traduisent pas une diminution de volume d'un hémicrâne par rapport à l'autre (obliquité bien connue de certains crânes de nourrissons toujours couchés sur le même côté: proéminence frontale d'un côté, occipitale de l'autre). Ce phénomène se retrouve également dans la *plagiocéphalie.*

2. *Hyperpression:*

Une hyperpression peut être occasionnée dans un hémicrâne par un hydrome cérébral, une tumeur, un hématome sous-dural. Les phénomènes inverses de ceux qui sont cités précédemment peuvent alors se



a. b.

Fig. 10. Diagnostic différentiel de l'a. c. u. Signe osseux d'hyperpression. a. A droite: petite aile abaissée, amincie; crista galli déportée vers la gauche; amincissement et bombement de la voûte; hypopneumatisation discrète des cellules mastoïdiennes.
(M . . . José, 4 ans; astrocytome fibreux calcifié.)

b. Porencéphalie frontale droite, qui entraine: un bombement et un amincissement osseux localisés.
(. . . Robert 21 mois.)

produire (Fig. 10), c'est à dire amincissement de l'os dans les zônes d'hyperpression avec bascule de l'apophyse crista-galli en sens inverse ou abaissement du rocher du côté de l'hyperpression. La comparaison entre les deux hémicrânes ne devra pas, dans ces cas, faire suspecter une atrophie cérébrale unilatérale.

Conclusion

Les modifications craniennes des atrophies cérébrales unilatérales ont été décrites chez le grand enfant et l'adulte.

C'est le grand mérite de FISCHGOLD d'avoir attiré l'attention sur les signes précoces et en particulier sur le déplacement apparent de la fontanelle.

Il résulte de nos observations que les signes osseux se développent très rapidement, en quelques mois, et que l'asymétrie globale, l'épaississement du diploë, l'aspect lisse de la table interne constituent, au cours de la première enfance, des signes positifs importants.

RÉSUMÉ

Les Auteurs insistent sur la précocité des signes radiologiques osseux d'atrophie cérébrale unilatérale: asymétrie globale, affaissement de la voûte, épaississement du diploë et aspect lisse de la table interne.

Ils discutent les asymétries physiologiques et les asymétries dues aux hyperpressions.

SUMMARY

The authors point out the early appearance of radiologic bone signs in unilateral cerebral atrophy: asymmetry of the skull, depression of the vault, thickening of the diploë and a smooth appearance of the internal table.

Physiologic asymmetry and asymmetry due to increased pressure are discussed.

ZUSAMMENFASSUNG

Der Verf. hebt das frühzeitige Auftreten radiologischer Knochensymptome bei der unilateralen Hirnatrophie hervor: Asymmetrie des Schädels, Depression des Schädeldaches, Verdickung der Diploë und ein glattes Aussehen der Tabula interna. Die physiologische Asymmetrie sowie die auf Druckerhöhung beruhende Asymmetrie werden diskutiert.

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FROM KING GUSTAF V JUBILEE CLINIC, LUND, SWEDEN (DIRECTOR: BERTIL EBENIUS)

ROENTGEN TREATMENT OF GLIOMATA

by

Martin Lindgren

Introduction

Since the institution of a neurosurgical department at the University Hospital, Lund, in September 1946, an ever increasing number of cases of cerebral tumour have been referred for radiotherapy to King Gustaf V Jubilee Clinic. Until that time we had few cases of this kind.

During the period 1946—1951 irradiation of glioma was given in cases in which the tumour was removed completely or partially, in cases in which the tumour was proved histologically by exploration and biopsy or by diagnostic puncture only, and in cases diagnosed roentgenographically but not proved histologically. The total number of cases of cerebral tumour referred to us during the period was 163.

Diagnostic puncture was done mainly in cases in which the situation of the tumour was such that surgical intervention would have involved undue risks. In recent years histologically verified but unoperated cases of glioma have been referred for radiotherapy with increasing frequency.

Roentgen examinations including routine films of the skull, encephalography, ventriculography and angiography will practically always show the presence of expansive processes. These examinations generally show the situation and size of the tumour with satisfactory accuracy for the neurosurgeon. Angiography is sometimes the first roentgen examination and is often sufficient to localize the tumour for diagnostic puncture. If biopsy then reveals a malignant glioma, the patient is often referred for radiotherapy without further roentgen investigation.

More accurate roentgenologic localisation of the tumour and accurate knowledge of its size are, however, necessary for the adequate planning of radiotherapy and for preventing failure on account of insufficient dosage or irradiation of only part of the tumour. Clinical data and above all observations made at any previous operation are often of great value.

In the latter part of the period covered by the present series, radiopaque tantalium powder was sometimes applied to that area of the operative cavity where it was thought that part of the tumour might have been missed. This facilitated location of the suspected area for postoperative radiation therapy, if necessary.

Good palliative results, but hardly any cures, have been reported in the literature. This may be due to various factors. The tumour dose may have been too small or the tumour may have been radioresistant. It is also possible that the dose delivered to some parts of the tumour was not large enough, even though the entire tumour was irradiated, and, finally, it is possible that inaccurate information about the size and situation of the tumour resulted in part of it being missed by the roentgen rays, so that it could grow in its periphery more or less unhindered.

Technique

As to the technique, all of the tumours were irradiated from several fields, there being four if the tumour was situated in the cerebrum and three when localized to the cerebellum. The skin dose per field was at most 4,000 r. All skin dose measurements included back-scatter. This meant a tumour dose of 5,000 r to 7,000 r. The target—skin distance was 50—60 cm; other factors: 170 kV; 15 mA; ½ mm Cu, 1 mm Al; HVL 0.9 mm Cu. The fields were about 8 cm by 8 cm.

The entire tumour was irradiated from every field. One field was treated per day and the skin dose delivered per field from the very beginning was 500 r, excepting in cases of medulloblastoma and ependymoma, in which the skin dose was 300 r or 400 r. Treatment was given in the form of two series. Usually 2,500—3,000 r per field were delivered in the first series and one month later, a further 1,000—1,500 r. The total treatment was usually spread over 60—80 days. Irradiation was started as soon as possible, sometimes a few days after operation. As a rule recurrences after a complete course received no further irradiation. Recently, patients with medulloblastoma have also received prophylactic irradiation of the spinal canal.

In order to judge the value of the method used routinely for the last five years, 120 cases of histologically verified glioma that had received radiotherapy at Lund were selected. Eight histologically verified cases of glioma referred to us were not included because four received no irradiation and four had been treated at some period elsewhere.

Classification of Gliomas

The histologic material was re-examined by the Director of the Pathological Department of the University of Lund, Professor C.-G.

AHLSTRÖM, who graded the cases in accordance with RINGERTZ's classification. For the groups of cerebral gliomas comprising astrocytomas, astroblastomas and glioblastomas RINGERTZ employed a 3-step grading: astrocytoma, intermediate type and glioblastoma. The tumour is graded according to the most anaplastic portion of the biopsy specimen. Of these grades the astrocytoma is the least malignant and the glioblastoma the most malignant. RINGERTZ's grading system differs in certain respects from the four-step system suggested by the Mayo Clinic.

The same author also adopted a special grouping for ependymomas and oligodendrogliomas.

Table I shows the present series. It is clear that about five sixths of all cases fell within the 3 above-mentioned types.

Results

Table I also summarizes the results. Most of the cases have not yet been followed up long enough to permit calculation of the 5-year cure rate. Of these 120 patients, 92 have died and on Sept. 1, 1952 28 were still alive. Of these 28 survivals, 14 have been followed up for more than 2 years, 2 of them (with benign ependymomas) for more than 5 years. Seven of these 14 are continuing their former occupation: the working capacity of the remaining 7 is decreased. Of all the 28 survivals, 13 have returned to their usual work and 12 are partially disabled.

Table I

Histologically verified gliomas

Results of roentgen treatment
1/9 1946—31/12 1951

	Number of cases	Deaths 1/9 1952	Survivals[1] 1/9 1952
Glioblastoma	53	48	5 (2)
Intermediate type	26	19	7 (4)
Astrocytoma	18	12	6 (2)
Medulloblastoma	11	8	3 (1)
Benign ependymoma	5	1	4 (4)
Malignant ependymoma	3	3	—
Glioblastoma with traces of ependymal origin	1	—	1
Pinealoma	2	1	1 (1)
Oligodendroglioma	1	—	1
	120	92	28 (14)

[1] Number of patients observed more than 2 years is given in brackets.

Table II

Mortality during and after radiotherapy

	Deaths during						
	treatment	1st year	2nd year	3rd year	4th year	5th year	> 5 years
Glioblastoma	11	36	10	—	1	—	—
Intermediate type	—	14	3	2	—	1	—
Astrocytoma	—	5	2	3	—	—	2
Medulloblastoma	—	4	3	1	—	—	—
Benign ependymoma	—	1	—	—	—	—	—
Malignant ependymoma	—	3	—	—	—	—	—
Glioblastoma with traces of ependymal origin	—	—	—	—	—	—	—
Pinealoma	—	—	—	1	—	—	—
Oligodendroglioma	—	—	—	—	—	—	—
	11	63	18	7	1	1	2

The duration of survival is summarized in Table II, from which it is clear that 29 of the 92 lived more than 1 year, and 11 more than 2 years. Sixty-three died within 1 year of the commencement of radiotherapy.

Complications

Eleven of the patients died before the completion of the roentgen therapy. In one of these, death was due to acute infection. The records of the remaining 10 were examined, especially with regard to so-called pre-reaction (BÉCLÈRE), *i. e.* acute increase in intracranial pressure at the beginning of the roentgen treatment.

It was found that a diagnostic puncture had been carried out in 8 of these 10 cases, subtemporal decompression in 1 and in the remaining case the tumour had been partially removed. In 5 of the 8 cases and in the 2 that had been operated on the disks were choked.

The following are two illustrative examples.

A man O. N., aged 60, complained of increasing headache and loss of memory. Both disks were choked and haemorrhagic. He was mentally deteriorated. Roentgen examination revealed a large tumour on the right side in the region of the corpus callosum. Diagnostic puncture: glioblastoma. Irradiation with an initial dose of 400 r was administered. On the seventeenth day after the beginning of treatment, clinical signs of raised intracranial pressure were noticed, and five days later the patient died. Post-mortem examination revealed signs of increased intracranial pressure and tumour growth through the corpus callosum into the opposite hemisphere.

There were no signs of so-called pre-reaction in this case. The fatal issue was probably due mainly to the extensiveness of the tumour and not to radiation.

A woman M. F., aged 59, when first seen had a month's history of increasing head-

ache, vomiting, giddiness and mental haziness. Both disks were choked. Roentgen examination showed a tumour in the right temporal region, and diagnostic puncture confirmed the presence of a glioblastoma. The patient was irradiated with an initial dose of 500 r. She was disorientated, restless and required sedatives before treatment. After the first session, the temperature began to rise. She then became soporous and was completely paralysed on the left side. Dehydration produced some improvement, but 2 days later death occurred. Post-mortem examination showed a large tumour in the right hemisphere extending into the opposite hemisphere, and widespread necrosis, but no signs of raised intracranial pressure.

There was probably pre-reaction in this case.

Analysis of the case records of the patients who had died before completion of treatment revealed that 2 of the 5 with choked disks and submitted to diagnostic puncture had shown obvious symptoms of raised intracranial pressure already at an early stage of the treatment. This was also true for 2 of the 4 patients with normal disks and submitted to diagnostic puncture, and for 1 of the 2 operated cases with choked disks. In all of these 5 patients with increased intracranial pressure, the initial dose delivered was 500 r; the tumour was an inoperable, extensive malignant glioma, as a rule with widespread necrosis and haemorrhages and sometimes with cortical involvement.

In addition to these cases, there were 62 with choked disks. These received an initial dose of 300, 400 or 500 r, and in no instance were signs of increasing intracranial pressure observed during the first part of the treatment but in 34, the papillary stasis subsided. Moreover, in irradiation of hypophyseal tumours through fields 25 centimetres square with an initial dose of 500 r delivered over the temporal region, we have never noticed any subsequent increase in intracranial pressure. Neither were any such signs seen in a case which we treated in co-operation with Dr. LEKSELL: in this case the rays were directed stereotactically to the pituitary, and the initial skin dose was four times 300 r to fields 10 square centimetres in size. The daily skin dose was gradually increased to 2,100 r, corresponding to a tumour dose of almost 700 r, without any subsequent undesired reaction.

In our 120 cases of glioma treated with an initial dose of 300, 400 or 500 r, increasing intracerebral pressure with a fatal issue occurred in 5 cases, but this complication is independent of any papilloedema or surgical decompression.

Our experience seems to suggest that a pre-reaction is most likely to appear in cases of tumour in which the intracranial pressure is already increased and in which even a slight further increase in pressure is sufficient to cause threatening or fatal compression.

The 63 patients that succumbed within one year of treatment are accounted for in Table III. Of these, 28 died within 1 to 6 months after the beginning of the radiation therapy and 24 during the following 6 months.

Table III

Mortality within 1 year after beginning of irradiation

	Deaths during							
	treatment	1—2 months	2—3 months	3—4 months	4—5 months	5—6 months	7—12 months	Total
Glioblastoma	11	4	—	5	3	4	9	36
Intermediate type	—	2	—	3	1	—	8	14
Astrocytoma	—	1	1	—	—	1	2	5
Medulloblastoma	—	—	—	1	1	—	2	4
Benign ependymoma	—	—	—	—	—	—	1	1
Malignant ependymoma	—	1	—	—	—	—	2	3
Glioblastoma with traces of ependymal origin	—	—	—	—	—	—	—	—
Pinealoma	—	—	—	—	—	—	—	—
Oligodendroglioma	—	—	—	—	—	—	—	—
	11	8	1	9	5	5	24	63

We attempted to obtain evidence as to whether the irradiation could in any way be held responsible for these deaths. An analysis of the records showed that the relapse frequently appeared suddenly and that then ran a rapid course. The patients often felt much better or even very well for some time, and then broke down. According to our neurosurgeons, this type is naturally not seen as a rule after surgical intervention only. It is not possible clinically to differentiate cerebral oedema, haemorrhage and tumour progression. It does not sound unreasonable to suppose that the decompressive effect of irradiation is sometimes only brief. So far, only a few cases have been submitted to autopsy, which has unfortunately not helped to solve the problem. Many of the patients who succumbed within the first 6 months probably died from radioresistant tumours.

Radiosensitivity

The radiosensitivity of the different types of glioma was assessed on the basis of 92 cases that had received a complete 2-stage irradiation course. It was often difficult to say how much the operation, and how much the irradiation had influenced the further course. Three groups were distinguished: one consisting of those cases in which the tumour was regarded as radiosensitive, *i. e.* when irradiation was followed by a distinct improvement, though sometimes fairly brief, in the condition of the patient; a second group consisting of cases in which it was not pos-

Table IV

Radiosensitivity in 92 cases. Complete irradiation

	Total nr	Total or partial extirpation				Diagnostic puncture or exploration + biopsy			
		Nr of cases	Radiosensitivity			Nr of cases	Radiosensitivity		
			+	?	—		+	?	—
Glioblastoma	35	21	1	14	6	14	6	1	7
Intermediate type	20	16	4	4	8	4	2	—	2
Astrocytoma	15	8	1	5	2	7	4	1	2
Medulloblastoma	11	2	—	2	—	9	9	—	—
Benign ependymoma	5	4	3	1	—	1	—	1	—
Malignant ependymoma	2	1	—	—	1	1	1	—	—
Glioblastoma with traces of ependymal origin	1	1	1	—	—	—	—	—	—
Pinealoma	2	1	1	—	—	1	1	—	—
Oligodendroglioma	1	1	—	1	—	—	—	—	—
	92	55	11	27	17	37	23	3	11

sible to say whether the improvement should be ascribed mainly to the operation or to irradiation and a third group consisting of cases in which irradiation was not followed by any improvement (Table IV). As mentioned above, irradiation was usually started shortly after the operation; therefore it is possible that the radiosensitive group contained some cases in which the improvement was ascribable to surgery.

It is clear that the glioblastoma and the intermediate type were sometimes obviously radiosensitive. Strangely enough, astrocytomas occasionally were sensitive. Although the radiosensitivity may in some cases be only apparent and due to the slow course this type of tumour runs, in others it is real, and occasionally, very marked.

Two case reports which illustrate the radiosensitivity of these tumours are given below.

Glioblastoma. H. O., farm-labourer, aged 46. For the previous 4 weeks he had suffered from headache of increasing severity, nausea with vomiting and disturbed sense of balance. Both disks were choked. There was weakness of the muscles of the left arm and leg. Ventriculographic examination revealed an expansive tumour in the posterior of the right parietal region. Diagnostic puncture in December, 1948 showed histologic features of glioblastoma. The patient received post-operative irradiation with an estimated tumour dose of 6,000 r spread over 72 days. At the end of the therapy the patient felt well and the papilloedema had subsided. In May, 1949, he began full-time work, and when reviewed in September 1949, neurological examination revealed nothing remarkable. The disks were no longer choked. In the middle of December 1949, he again complained of giddiness, headache and impaired vision. Death occurred in February 1950.

Astrocytoma. H. W., engineer, aged 39. Operation in February 1946 for astrocytoma in the left parietal lobe. The tumour was aspired without any attempt at a radical removal. In the spring of 1946 he received radiotherapy. The calculated tumour dose was 6,800 r delivered in the course of 84 days. In the beginning of treatment the right arm and the right leg were weak, the patient was mentally sluggish, and the right disk was choked. After irradiation he gradually improved, took part-time employment and in January 1947, felt well and was again working full-time. He was promoted in the company for which he was working, but in 1949 disabling hemiplegia occurred. He gradually got worse and died 3 years later.

The problem of radiosensitivity is well illustrated by observations made in the 40 patients submitted to diagnostic puncture only. Of these, 18 died before the completion of treatment. Histologic examination of the specimen showed a glioblastoma in 13 cases, an intermediate type in 4 and an astrocytoma in 1 (with central situation of tumour). All of these 18 patients died within 1 year, 15 within 2 months, of the commencement of radiotherapy.

Of the 22 who received a complete course of treatment, 18 have died and 4 are still alive. Of the 18 non-survivors, 6 died within 6 months of treatment, 3 in the course of the second 6 months of treatment, 6 in the course of the second year and 3 after up to five years.

Of these 18 non-survivals, 8 had a glioblastoma; 2 of these returned to their usual work for 6 and 7 months respectively. Two had a tumour of intermediate type; 1 was able to do full-time work for at least a year. Two had an astrocytoma and were able to work for 1 and 5 years.

Discussion

In the treatment of gliomata it is the rule at the department to try to deliver an adequate tumour dose within a reasonably short period. This requires large daily skin doses, because the tumour dose diminishes rapidly with increasing depth of the growth. After a skin dose of 2,500—3,000 r per field we generally interrupt the course for about a month. This prevents undue radiation reaction. A disadvantage of such interruption is, however, that an adequate tumour dose requires a much larger skin-dose than it otherwise would. In our experience a tumour dose of 7,500 r spread over 80 days will not produce a more favourable biologic effect than 6,000 r spread over 30 days. Therefore, it would seem advantageous not to interrupt the treatment, and, when possible, even to increase the daily doses.

In 75 of our cases of glioma the tumour dose was calculated. In every group the skin-dose was one and the same, but the tumour dose varied widely with the depth of the growth. Owing to the smallness of the series and shortness of the follow-up period it is, as yet, not possible to deduce what dose may be adequate in a given case.

Nevertheless certain observations suggested that the favourable dose for radiosensitive cases of glioblastoma sometimes need not exceed 7,500 r spread over 60 to 80 days and that the radiosensitivity of the intermediate type varies widely although here again no definite doses can be prescribed. It also appeared that some astrocytomas are radiosensitive and may react favourably to the same dose as glioblastomas, that medulloblastomas and pinealomas often are extremely sensitive and that the most favourable tumour dose in children is probably about 5,000 r spread over 60 to 80 treatment days.

The positive contribution of the analysis of the series to the discussion on gliomas is that, in contrast to what is often assumed, it showed that *astrocytomas are not always radioresistant and that irradiation can sometimes produce fairly long cures.*

In many instances of different types of gliomas fairly long relief was given, and although post-mortem examination did not show the complete disappearance of a cerebral tumour, it revealed a response of the tumour tissue to radiation. In none of our cases submitted to post-mortem examination did we see signs of destruction of normal tissue surrounding the tumour. This suggests that the dose used, *i. e.* 7,500 r spread over 60—80 days, is on the small side and in some cases probably too small to produce the desired effect.

The experience gained from this series suggests that for irradiation of a tumour to be adequate it is necessary to know its histologic type, its situation and its size.

It has also taught us the wisdom of:

commencing irradiation as soon after operation as the general condition of the patient permits,
treating all gliomas with irradiation, but not in moribund cases,
continuing with multi-field technique with variation in the number and size of the field so that the entire tumour is always irradiated from every field,
employing stereotactically directed irradiation in selected cases,
limiting the initial dose to 200 r,
watching the patient closely for any increase in intracranial pressure and considering prophylactic subtemporal decompression,
giving treatment in the form of a single uninterrupted course with larger doses towards the end, *i. e.* doses of more than 500 r,
varying the tumour dose according to the sensitivity of the type of glioma.

Finally, it should be stressed that the above suggestions are only based on a preliminary analysis made for the purpose of obtaining some guidance in the future treatment of gliomas.

The opportunities for continued studies of problems bearing on gliomas are exceptionally favourable at Lund, where both the neurosurgical and the radiologic departments cover one and the same receiving area. All gliomas occurring in this area, covering about one quarter of the population of Sweden, are referred to us.

SUMMARY

An analysis of 120 verified cases of cerebral glioma treated at King Gustaf V Jubilee Clinic, Lund, during the period 1946—1951 and histologically graded by the RINGERTZ's classification suggested the following conclusions:

Knowledge of the histologic type of the tumour, its situation and size is necessary for adequate planning of radiotherapy.

The initial tumour dose, previously usually 300—500 r, should be limited to 200 r to avoid any complicating and sometimes fatal increase in intracranial pressure.

Cerebral tumours, even astrocytomas, are often radiosensitive; this is best shown by cases in which irradiation is preceded by diagnostic puncture only.

Treatment should be given in a single uninterrupted course.

ZUSAMMENFASSUNG

120 Hirngliome, die während der Jahre 1946—1951 in der Jubileumsklinik in Lund röntgenbestrahlt worden sind, wurden analysiert. Die histologische Klassifikation geschah nach der von RINGERTZ angegebenen Methode. Als Schlussfolgerungen ergaben sich:

Für adekvate Planlegung der Strahlentherapie ist Kenntnis des histologischen Typus des Tumors, dessen Lokalisation und Ausdehnung notwendig.

Die erste Bestrahlungsdosis, bisher 300—500 r, wird zu Vermeidung von manchmal fataler Steigerung des intrakraniellen Druckes auf 200 r begrenzt.

Hirngliome, auch Astrozytome, sind oftmals strahlenempfindlich. Diese Tatsache geht am besten aus der Beurteilung der Fälle hervor, die vor der Bestrahlung nur einer diagnostischen Gehirnpunktion unterzogen worden sind.

Rie Röntgenbehandlung sollte in einer einzigen ununterbrochenen Serie gegeben werden.

RÉSUMÉ

L'analyse de 120 cas vérifiés de gliome cérébral, traités à la Clinique du Jubilé du Roi Gustave V, à Lund, dans la période 1946—51 et rangés histologiquement suivant la classification de RINGERTZ, suggère les conclusions suivantes:

Il est nécessaire, pour établir le plan convenable de la radiothérapie, de connaître le type histologique de la tumeur, son siège et son volume.

La dose initiale à la tumeur, habituellement jusqu'à maintenant de 300—500 r, devrait être limitée à 200 r pour éviter toute hypertension cranienne qui est une complication et est parfois fatale.

Les tumeurs cérébrales, même les astrocytomes, sont souvent radiosensibles, la meilleure preuve en est donnée par les cas où la radiothérapie n'a été précédée que par une ponction diagnostique.

Le traitement devrait comporter une seule série ininterrompue.

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FROM THE MONTREAL NEUROLOGICAL INSTITUTE, MONTREAL, CANADA

BONY ABNORMALITIES IN THE REGION OF THE FORAMEN MAGNUM: CORRELATION OF THE ANATOMIC AND NEUROLOGIC FINDINGS

by

D. L. McRae

In the course of a review of the radiologic findings in syringomyelia and syringobulbia at the Montreal Neurological Institute, it was found that 38 % of the patients had bony abnormalities in the region of the foramen magnum. It was therefore decided to study all the patients with bony abnormalities in this region and to try to correlate the anatomic findings with the symptoms and signs. Over one hundred patients were available for analysis out of which I have selected four groups for discussion.

(a) Occipitalization of the atlas, 28 cases.
(b) Pure platybasia and basilar invagination, 21 cases.
(c) Separate odontoid process of the axis, 11 cases.
(d) Chronic atlanto-axial dislocation, 6 cases.

The remaining cases formed a miscellaneous group, impossible to analyze. Some consisted of anomalies to which no name could be given, while others had combinations of the above-mentioned abnormalities.

Occipitalization of the Atlas

This anomaly may also be called assimilation of the atlas to the base of the skull or atlanto-occipital fusion. The largest groups that have been reported are in the anatomic literature and, for the most part, consist of collections of dried skulls. The vertebral column is usually not described. I believe that much of the confusion regarding occipitalization of the atlas and manifestation of an occipital vertebra is unnecessary. If the criteria found in the dried skulls are considered

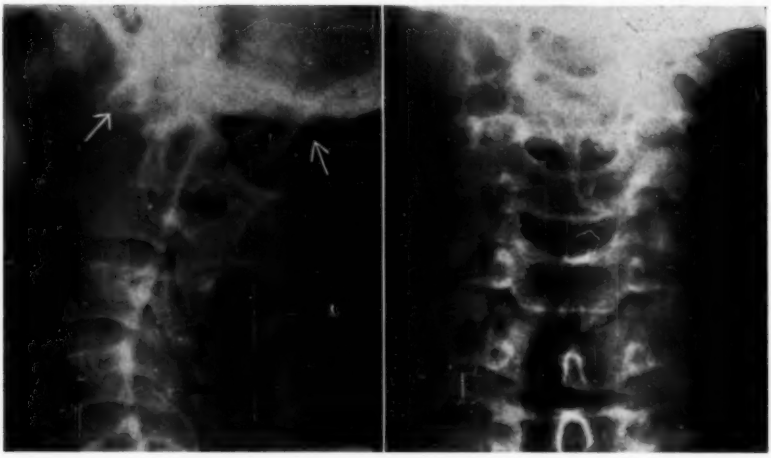

Fig. 1. Arrows point to the assimilated anterior and posterior arches. (Case A. A. Male, age 45. The provisional diagnosis had been tumour of the medulla oblongata.)

less absolute, if the cervical vertebrae are carefully inspected, and if the hypoglossal nerves and vertebral arteries can be seen, one will seldom make the diagnosis of an occipital vertebra. As FRAZER (1) says, "It is a very rare thing to see a segment of this sort (part of the occipital below the hypoglossal foramen) showing more or less completely, or nearly completely, but it is not so very uncommon to see some formation or accentuation around the margin of the foramen magnum which may represent a local vertebralization of the occipital of this particular region: the appearance of a median condyle for example may be merely a failure in absorption of the central part of the last-included segment, accentuated posterior margins may show a similar failure in the neural arch, or a prominence of the ex-occipital (paramastoid process) may indicate a potential transverse process which has not sunk its individuality completely."

The essential point in the diagnosis of occipitalization of the atlas is some degree of bony union between the skull and the atlas. (Figs. 1, 2, 3, 4, 5.) The parts of the atlas that must be clearly visualized are the anterior and posterior arches, the superior facets and the transverse processes. Any or all of these may be fused with the skull. One lateral half of the atlas may be completely assimilated and the other half not. (Figs. 6, 7, 8.)

Fig. 2.

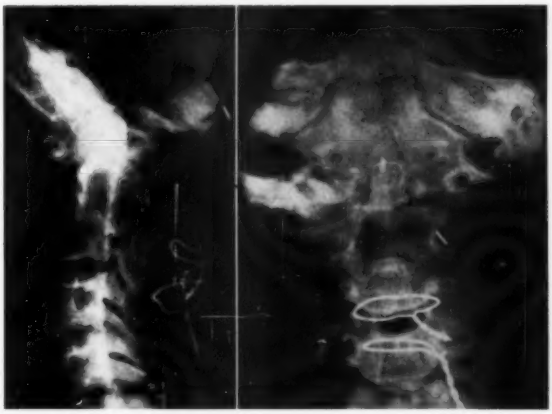

Fig. 3.

Figs. 2 & 3. (Same case as fig. 1.) 2. Midsagittal laminogram. 3. Radiographs of the post-mortem specimen. (The patient died six months after operation.)

Fig. 4. Arrows point to the assimilated anterior and posterior arches. (Case F. B. Male, age 22. The provisional diagnosis had been "Brain stem lesion, possibly tumour".)

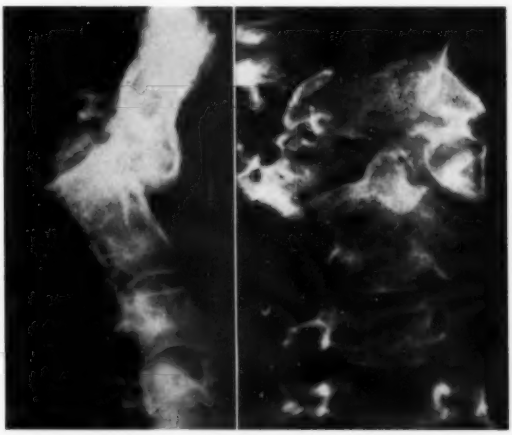

Fig. 5. (Same case.) Radiographs of the post-mortem specimen. (The patient died two months after operation.)

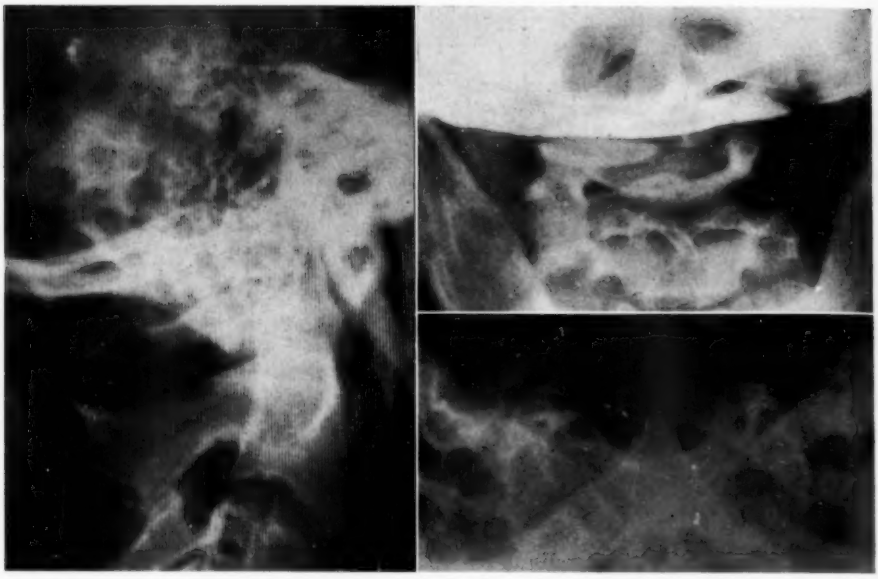

Fig. 6. Asymptomatic case showing the left half of the posterior arch of the atlas not assimilated. (Case S. M. Male, age 68.)

It is important to realize that platybasia and basilar invagination are uncommon in association with assimilation of the atlas. Even when present they are slight and unimportant. Four of the twenty-eight patients had basal angles of 145 degrees and only two of these had neurologic signs. Three of the twenty-eight had basal angles of 150 degrees and only one had neurologic signs. Seven of the twenty-eight had slight to moderate basilar invagination. Of these, three had no neurologic signs and four had neurologic signs. Seventeen had neither platybasia nor basilar invagination.

The most significant findings were related to the odontoid process of the axis. If the odontoid was excessively long or unusually high in position, or if it was angulated posteriorly, symptoms and signs were usually found. If the anteroposterior diameter of the spinal canal behind the odontoid process was 19 mm or less, there were always neurologic signs. If the odontoid process moved back and forth (Fig. 9) more than 3 mm on flexion and extension of the head, neurologic signs were always present. In the two cases of occipitalization of the atlas that came to autopsy there was a depression in the anterior surface of the medulla oblongata into which the odontoid projected. In fifteen

Fig. 7. The right transverse process (1) of the atlas and the lateral mass are not assimilated. The left transverse process is absent but a left paramastoid process is present (2). The left lateral mass is assimilated. (Case T. C. Male, age 39. Suboccipital aching pain was the patient's only complaint.)

of the twenty-eight cases the odontoid process lay more than 3 mm behind the anterior arch of the atlas and in most cases this was the reason why the antero-posterior diameter of the spinal canal was reduced at this level. In these cases, and also in some of the others, the antero-posterior diameter of the spinal canal at the level of the odontoid was reduced by a bony fringe projecting inwards and downwards from the posterior lip of the foramen magnum. This bony fringe represented an assimilated posterior arch of the atlas.

The second and third cervical vertebrae were fused in eighteen of the twenty-eight cases but this did not seem to be of any clinical significance.

Oil myelography was not carried out in any of these patients but gas myelography was valuable in showing herniation of the cerebellar

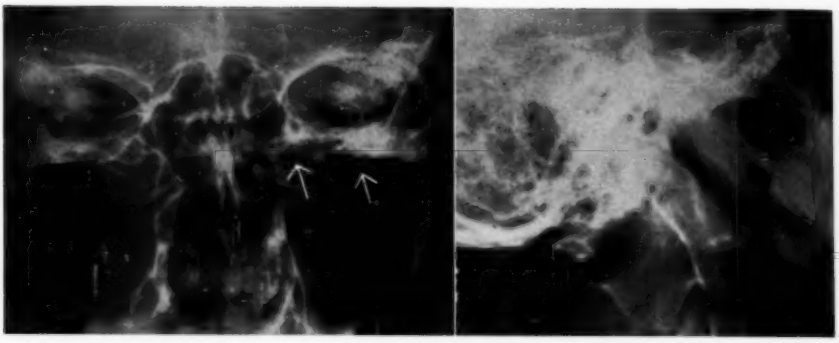

Fig. 8. The left lateral mass of the atlas and the transverse process are assimilated (arrows). The right lateral mass and transverse process are not. (Case F. P. Male, age 25. Epilepsy. No abnormal neurologic signs.)

tonsils, the Arnold-Chiari malformation, and the presence or absence of a dural band pressing against the back of the cord at the level of the foramen magnum.

The average age at which symptoms appeared was 31 years. The youngest symptomatic case, a girl of 15 years, had her first symptoms at age 7. The oldest symptomatic case, a man of 48 years, had had symptoms since the age of 45.

The neurologic symptoms and signs often appeared after a head or neck injury yet in none of these patients was a fracture shown.

Neurologic symptoms seemed to be due to the occipitalization of the atlas in nineteen of the twenty-eight cases. (Table 1.) Weakness or ataxia of the legs was the most frequent complaint, occurring in

Table 1

Occipitalization of the Atlas
28 Cases: 22 male, 6 female

Neurologic Symptoms in 19 Cases		*Neurologic Signs in 17 Cases*	
Weakness and ataxia — legs	14	Long tract deficit — arms	13
» » » — arms	10	» » » — legs	11
» » » — both	9	Ataxia — arms	7
Numbness and pain — arms	11	» — legs	6
» » » — legs	4	Nystagmus	9
» » » — both	4	Bulbar signs	6
Headache	11	Post. column defect — arms	4
Neck pain	7	» » » — legs	8
Visual symptoms	7	Two-point loss astereognosis — arms	6
Auditory symptoms	5	— legs	2

a. b.

Fig. 9. Head bent backwards (a), forwards (b). In b the odontoid process has moved back several millimeters. (Case A. L. Male, age 22. Diagnosis on admission: syringomyelia. At operation the spinal cord was shown to contain cysts.)

fourteen patients. Numbness and/or pain in the extremities was the next most frequent symptom, in eleven cases being situated in the arms and in four in the legs (these four also had numbness and pain in the arms). Dull aching pain in the occiput or upper neck was noted in eleven cases but there was never any pain of root character, nor was there hyperaesthesia or hypaesthesia in the second cervical dermatome. Seven patients complained of blurring of vision or diplopia which I cannot explain. Earache and buzzing in the ears was mentioned prominently by five patients, and which again I am unable to explain.

Neurologic signs were found in seventeen cases, usually in the motor system (hyperreflexia, Babinski and Hoffman signs, weakness, etc.). Motor signs were encountered in the arms and legs in thirteen patients, and in the arms alone in two patients. Ataxia was frequent and occasionally very severe. Posterior column signs were present in the arms and legs of eight cases and in the arms alone in four. Six patients showed reduction of two-point discrimination or stereognosis in the hands and two patients had similar signs in the feet. Four patients had considerable loss of pain sensation in the hands. Six cases had slight generalized reduction in sensation in the upper extremities and four in the lower extremities. Two patients presented Horner's syndrome. Nystagmus occurred in nine.

Of the patients who had neurologic signs or symptoms that might be attributed to the occipitalization of the atlas, three had dull aching occipital and suboccipital headache with vague or minimal signs and symptoms and two others had suboccipital aching pain and nothing else. This pain was not suggestive of greater occipital root pain but more of muscle spasm. It was usually relieved by lying down and seldom aggravated by head movements. It was months before motor signs in the arms and legs were reported and until this happened hysteria, anxiety state, post-traumatic headache, myositis, etc. were usually diagnosed.

Nine of the patients showed a predominantly motor deficit in the extremities. The most frequent provisional diagnosis in these patients was multiple sclerosis but if the pain loss was striking (four patients) syringomyelia was likely to be diagnosed. Actual syringomyelia was proven at operation in several cases by the aspiration of collections of fluid within the upper cervical cord.

Three of the remaining patients were first thought to have a tumour. Papilloedema was present and the neurologic signs had progressed steadily from the onset. All of these three patients had involvement of at least one of the lower three cranial nerves.

Eight of the patients with occipitalization of the atlas were considered to have no symptoms or signs referable to the condition.

In three of the patients with occipitalization of the atlas, it was not possible to say whether or not there were neurologic symptoms or signs due to this lesion. The presence of other organic lesions (brain tumour, cervical disc protrusions, birth injury with epilepsy and mental retardation) made it hard to decide whether or not the occipitalization was producing any symptoms.

Platybasia and Basilar Invagination

Platybasia means flattening of the base of the skull, that is, a basal angle that approaches 180 degrees. The basal angle is the angle formed by the intersection of the plane of the clivus and the plane of the anterior fossa. Neither of these planes is easy to draw for several reasons. There are, in many subjects, three levels to the floor of the anterior fossa of the skull. The lowest is the cribriform plate which forms the floor of a trench in which lie the olfactory bulbs. The second plane is formed by a ledge of bone level with the top of the olfactory bulb formed by the superior surface of the ethmoid above the ethmoid air cells and by the adjacent part of the horizontal plate of the frontal bone. The third level is the highest point of the orbital roof. Which of these three is to be used in drawing the basal angle?

Fig. 10. The basal angle and MacGregor's base line in a case of basilar invagination. (Case R. D. Male, age 17.)

The plane of the clivus is easy to draw if the clivus is straight. However, about one-half of normal patients have a clivus that is concave as seen on the lateral radiograph or laminogram. In a large number of pathologic cases the clivus is convex posteriorly. How is one to choose the plane of the clivus? Most authors prefer to draw the cord of the curve in the case of a concave clivus and a tangent to the upper part of the curve in a convex clivus. In pathologic cases, this causes an exaggeration of the basal angle.

I have decided to use lines from the tuberculum sellae to the naso-frontal suture and to the anterior margin of the foramen magnum to subtend the basal angle. (Fig. 10.) Even these two lines are not easy to draw. The tuberculum sellae may be hard to identify if the sphenoid sinus is large and has converted the tuberculum to a large bulge, or if the chiasmatic groove is not a groove but a smooth sloping plane. The anterior margin of the foramen magnum is the point where the inferior cortex of the basi-sphenoid meets the clivus but occasionally a thin fringe of bone (ossification of the anterior atlanto-occipital ligament) hangs down from it and confuses this point. The anterior margin may be obscured by the petrosa and one may need a laminogram to identify it.

Basilar invagination or impression means an upward bulging of the margins of the foramen magnum. It may be a congenital abnormality

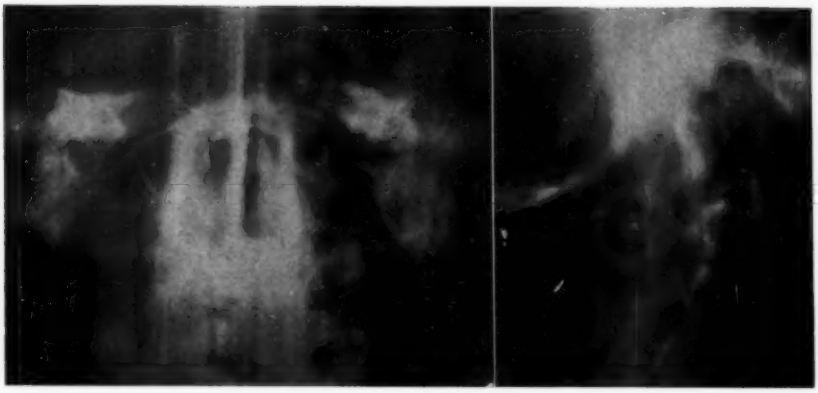

Fig. 11. Advanced case of basilar invagination; the atlas is however shown on the laminograms.

or secondary to softening of the bone about the foramen magnum. Since the occipital condyles bear the thrust of the spine they must be the first parts of the base to be displaced. If the tips of the condyles are seen at or above the foramen magnum line, basilar invagination must be present. The condyles are close to the anterior lip of the foramen magnum and presumably the anterior lip should rise to a greater degree than the posterior lip. This alteration in the plane of the foramen magnum is best shown by Boogard's (2) angle, the angle subtended by the plane of the clivus and the plane of the foramen magnum as seen in lateral projection. The range of the normal is from 119 degrees to 136 degrees. As the base invaginates, this angle increases. The upward curvature of the lateral edges of the foramen magnum may be seen in true lateral films of the skull and is another sign of basilar invagination. The tip of the odontoid process of the axis is above Chamberlain's line in about one-third of normal individuals. If the tip is more than 3 mm above Chamberlain's line, basilar invagination is almost surely present. McGregor's base line (from the hard palate to the lowermost surface of the occipital squama) is easier to draw and probably more significant than Chamberlain's line. In advanced cases the posterior edge of the foramen magnum rises and makes it difficult to see the atlas. In such cases one may be tempted to diagnose assimilation of the atlas. In order to make a differentiation in these cases, frontal and lateral laminograms will usually have to be obtained. (Fig. 11.)

Twenty-one cases of platybasia and/or basilar invagination were found in the group. In some patients both conditions were seen and

in others only one of the two was present. None of these cases had occipitalization of the atlas.

In three patients it was impossible to decide whether or not the bony lesion was causing symptoms or signs. Two of these complained only of headaches and presented no abnormal neurologic signs. The third patient had a feeling "that he was going to black-out" when he extended his neck. He had never "blacked-out" and his neurologic examination was within normal limits.

It was considered that eight of the patients had no symptoms or signs that could be caused by the foramen magnum lesion. The basal angle in this group varied from 127 to 153 degrees with an average of 142 degrees. Basilar invagination varied from slight (1 plus) to marked (3 plus), with an average of 2 plus. The tip of the odontoid process was from 9 to 21 mm above Chamberlain's line, with an average of 14 mm.

Ten cases had symptoms and signs that were considered to be due to the lesion. In this group the basal angle varied from 130 to 160 degrees, with an average of 146 degrees. Basilar invagination was present in all and averaged 2 plus. The tip of the dens was from 5 to 25 mm, with an average of 13 mm, above Chamberlain's line. In none of these cases did the dens project above the plane of the foramen magnum. In none was the antero-posterior diameter of the spinal canal behind the atlas or axis, less than 20 mm. The films obtained on bending did not show excessive mobility of the dens in any patient in this group.

Gas myelograms or posterior fossa encephalograms (Fig. 12) were performed in nine cases. In three, the cerebellar tonsils were below the foramen magnum but only one of these patients had symptoms. An Arnold-Chiari malformation was never shown by the contrast studies, nor was it found in the four cases which came to operation.

Five patients with platybasia and/or basilar invagination had Paget's disease (Fig. 13) and of these, two were asymptomatic. The other three had neurologic symptoms as well as neurologic signs.

A common finding was a convex clivus. It was found in twelve patients in contrast to only four patients in the group with assimilation of the atlas. The four patients who had assimilation of the atlas and a convex clivus all had slight basilar invagination or platybasia. There was often a hump at the spheno-occipital synchondrosis associated with a short basi-occipital, suggesting that this deformity was present before closure of the synchondrosis. Possibly early closure of this synchondrosis or hypoplasia of the basi-occipital played a part in producing the platybasia.

In only one case was there fusion of the second and third cervical vertebrae, this fusion being quite common in assimilation of the atlas.

The right atlanto-axial joint was at a different level, or had a dif-

Fig. 12. Gas myelography. The arrow points to the cerebellar tonsils below the foramen magnum. (Same case as in fig. 10.)

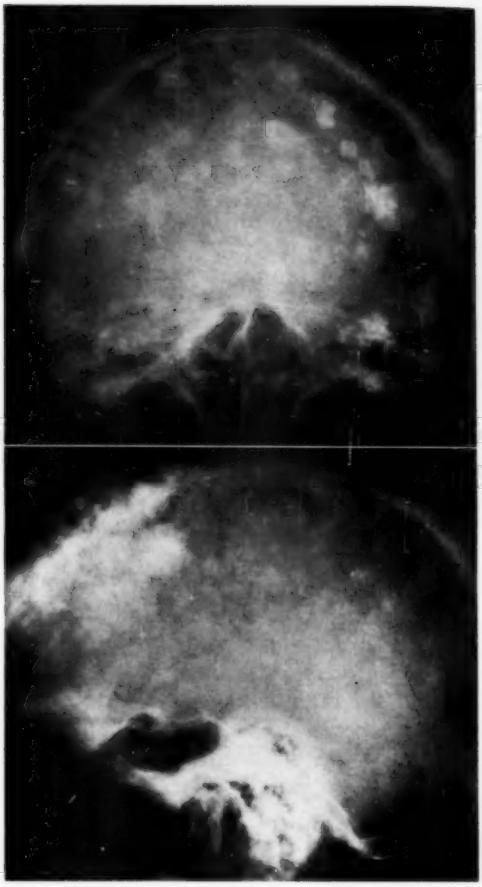

Fig. 13. Basilar invagination secondary to Paget's disease. (Case J. G. Female, age 49. Headache on straining or caughing and weakness of the arms and legs if she turned her head.)

ferent plane to the left in ten cases but this does not seem to be of any significance. (Fig. 14.)

The petrous tips were elevated in sixteen of the twenty cases in which standard A. P. skull films were made. In some cases the petrous tip on one side was higher than the tegmen tympani while on the opposite side it was lower than the tegmen.

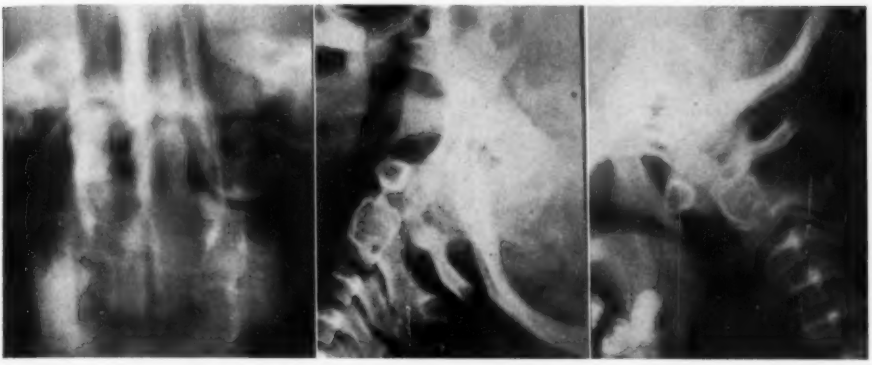

Fig. 14. Fig. 15 a. 15 b.

Fig. 14. The right atlanto-axial joint at a different level to the left in a case of basilar invagination. (Case C. H. Female, age 45.)

Fig. 15. Separate odontoid process of the axis; congenital abnormality. Head bent backwards (a), forwards (b). (Case R. P. Male, age 9.)

The anterior arch of the atlas could be seen well below the anterior lip of the foramen magnum in sixteen cases in contrast to assimilation of the atlas where the anterior arch was usually close to the basi-occiput. The posterior arch was usually close to, or touching, the posterior margin of the foramen magnum and in two cases seemed to lie inside the foramen magnum.

In all of the cases of platybasia and basilar invagination the dens was normal in shape and did not bend backwards more than 20 degrees. In assimilation of the atlas the dens was often abnormal in shape and direction.

Symptoms that were thought to be due to the lesion were present in ten cases. (Table 2.) The frequency of the various symptoms is a little different than in occipitalization of the atlas. Weakness or ataxia of the arms and legs was the most common symptom, while sensory complaints were rare. Numbness or pain in the extremities was mentioned by only two patients, headaches by two, and neck pain by one. There was blurring of vision in two patients but there were never complaints referable to the ears.

Two of these patients with symptoms had no neurologic signs. One of these stated that if she coughed or sneezed she would be dizzy for about five minutes and would stagger if she walked, as if intoxicated. The other, a boy, complained that if he flexed his head or exerted himself unduly he would get a pins and needles sensation in the occipital

Table 2

Platybasia and basilar invagination
21 Cases: 16 male, 5 female

Symptoms in 10 cases		*Signs in 8 Cases*	
Weakness and ataxia — arms	3	Long tract defect — arms	3
» » » — legs	5	» » » — legs	4
» » » — both	3	Ataxia — arms	2
Numbness and pain — arms	2	» — legs	2
» » » — legs	1	Nystagmus	1
Headache	2	Bulbar signs	2
Neck pain	1	Post. column defect — arms	2
Visual symptoms	2	» » » — legs	2
Auditory symptoms	0	Astereognosis — arms	2
		» — legs	1
		Horner's	2

region which would spread around the head. If he did not lie down at once an attack of bursting occipital headache with projectile vomiting and vertigo would come on and would last from twelve to twenty-four hours.

Eight patients with platybasia and/or basilar invagination had neurologic signs that were considered to be due to the lesion. The signs were less severe and less constant than in occipitalization of the atlas. It is worth noting that two of these patients had bulbar signs and two showed Horner's syndrome.

Of the ten patients with symptoms or signs, two were suspected of having intracranial tumours. The boy with the occipital bursting headaches and vomiting was suspected of having a colloid cyst of the third ventricle. One patient with unsuspected Paget's disease had headaches and attacks of numbness of the left arm and leg and the possibility of a parietal tumour was entertained. Two other patients were diagnosed clinically as having lesions of the foramen magnum; one, an example of advanced Paget's disease with ataxia and the other a twenty-four-year old girl with numbness and weakness of the legs and staggering gait who had had an occipital and upper cervical meningocoele removed shortly after birth.

Of the remaining six, four had previously been diagnosed as multiple sclerosis and two were diagnosed as syringomyelia.

Separate Odontoid Process of the Axis

Of the eleven examples of separate odontoid process, two were certainly congenital abnormalities. Both were found accidentally, one in a nine-year-old boy (Fig. 15) who had had a head injury and the other in a seven-year-old epileptic. In both cases the odontoid was fused to

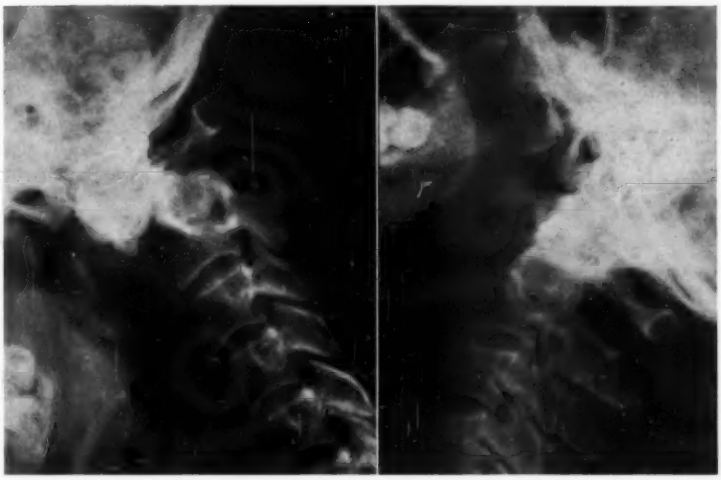

Fig. 16. A case of separate odontoid process with marked gliding of the atlas on the axis during flexion and extension of the neck. (Case R. G. Male, age 41. Spastic weakness of the legs for one year and of the arms for four months.)

the anterior lip of the foramen magnum but did not encroach on it. I do not think it is possible to decide in the adults whether we are dealing with an old ununited fracture of the odontoid or an anomaly. One of the patients had had a severe neck injury in childhood. Three others had had severe head injuries, thirty, twenty-three and three years before the recent symptoms began but on direct questioning denied that the

Table 3

Separate odontoid process of the axis
11 Cases: 8 male, 3 female

Neurologic Symptoms in 8 Cases			*Neurologic Signs in 8 Cases*		
Weakness or ataxia	— arms	6	Long tract defect	— arms	5
» » »	— legs	6	» » »	— legs	6
Numbness or pain	— arms	5	Ataxia	— arms	4
» » »	— legs	3	»	— legs	3
Headache		3	Nystagmus		1
Neck pain		5	Bulbar signs		0
Visual symptoms		0	Post. column deficit	— arms	3
Auditory symptoms		1	» » »	— legs	4
			Two-point loss astereognosis	— arms	2
				— legs	2
			Horner's syndrome		0

neck had been painful or stiff at the time of the head injury. The other five denied head or neck injury in the past.

In none of the group was there platybasia. Only two showed basilar invagination, and in both cases it was minimal. The striking finding was the marked gliding of the atlas on the axis during flexion and extension of the neck (Fig. 16). It varied from 5 to 25 mm and averaged 14 mm in the symptomatic cases and 10 mm in the asymptomatic cases. In all cases the separate odontoid process moved with the anterior arch of the atlas. The head flexed and extended at the atlanto-axial joint instead of at the atlanto-occipital joint, although in none was there evidence of bony fusion between the atlas and the skull. Occipital condyles and atlanto-occipital joint spaces were visualized in all cases and were entirely normal in eight. In three there was slight difference in the plane or level of the right and left atlanto-occipital joints. The separate dens was usually short and often small in anteroposterior diameter as well.

Three of the eleven cases were considered to be asymptomatic.

Eight of the eleven showed neurologic symptoms and signs. In three cases the patient had been referred with a provisional diagnosis of multiple sclerosis and in one, syringomyelia. Another, a nine year old boy, had had dizziness, occipital headache and staggering gait for three weeks and was suspected of having a posterior fossa tumour. Two others came to hospital with provisional diagnoses of fracture of the cervical spine. They had rather similar histories. One, an eighteen-year-old boy had had four attacks of an electric-shock-like sensation all over the body with temporary quadriplegia, brought on by sudden strain. The first three attacks had lasted only a few seconds but the last was of one hour duration. The other patient, a 57-year-old farmer, had been having similar sensations over the body with momentary quadriplegia for fifty years. Three days before admission he had bumped his head on the roof of a car and became quadriplegic but not unconscious.

Eight of the patients were male, three female. Three of the patients had had symptoms since childhood but the average age at onset of symptoms was 29 years.

Again, a slight preponderance of motor signs and symptoms was noted. There was no constant neurologic syndrome, however. Six patients had head pain and neck pain, not of the occipital neuralgia type but resembling that seen in muscle spasm or tension states.

Chronic Atlanto-Axial Dislocation

One of the best examples of this condition was almost certainly a congenital abnormality. All parts of the atlas were more delicate that

Fig. 17. Congenital atlanto-axial dislocation. (a). Head bent backwards, (b) forwards. (Case D. K. Male, age 5. A mentally retarded boy with torticollis and club foot. Neurologic examination within normal limits.)

I would expect in a five-year-old boy and there was a wide posterior spina bifida as well (Fig. 17). Two other cases had cervical block vertebra, one at C. 2—C. 3 and the other at C. 6—C. 7, suggesting the possibility that they might also have a congenital basis. Assimilation of the atlas, platybasia or basilar invagination were not present in any of these cases. The odontoid process was not particularly abnormal in shape. The three cases in which films on bending were obtained, showed little or no gliding of the atlas on the axis (0, 3 and 4 mm). They showed little or no movement of the skull on the atlas (0, 1 and 3 mm) flexion and extension taking place in the mid and lower cervical regions, al-

Table 4

Chronic atlanto-axial dislocation
6 Cases: 3 male, 3 female

Neurologic Symptoms in 4 Cases			*Neurologic Signs in 3 Cases*		
Weakness or ataxia	— arms	2	Long tract defect	— arms	1
» » »	— legs	2	» » »	— legs	3
Numbness or pain	— arms	3	Ataxia	— arms	1
» » »	— legs	1	»	— legs	0
Headache		1	Nystagmus		0
Neck pain		3	Bulbar signs		0
Visual symptoms		0	Post. column deficit	— arms	0
Auditory symptoms		0	» » »	— legs	0
			Two-point loss astereognosis	— arms	1
				— legs	0

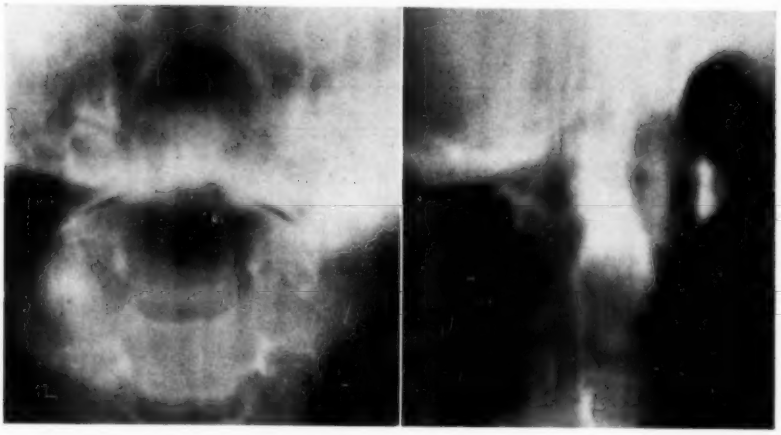

Fig. 18. Chronic atlanto-axial dislocation. (Case R. B. Male, age 56. Tingling sensations and weakness of the hands for about two years. Neck stiff but not painful.)

Fig. 19. Chronic atlanto-axial dislocation. (Case I. M. Female. Age 16. A mentally retarded girl who had had stiffness and soreness of the neck for three years. There were no abnormal neurological signs.)

Fig. 20. A—p view of the same case showing that the odontoid is not laying in the midline. This explains why the spinal cord was not compressed.

though the atlanto-occipital and atlanto-axial joints were visualized and seemed to be normal. The dens lay from 5 to 17 mm behind the anterior arch of the atlas, averaging 11.5 mm (Fig. 18). The depth of the spinal canal behind the dens was from 8 to 20 mm with an average of 15 mm. In three cases the odontoid not only seemed to be displaced posteriorly but also to one side and perhaps this lateral displacement allowed more room for the cord than would posterior displacement alone. Three of these patients with chronic atlanto-axial dislocation were considered to be asymptomatic, yet the deformitites seemed to be as severe as in the symptomatic cases. Two patients had neurologic signs and symptoms of moderate severity and had been diagnosed previously as multiple sclerosis. The sixth patient, a thirty-three-year-old woman, had no neurologic signs but had had a painful stiff neck for approximately six months.

Three of the patients were male, three female.

Symptoms, when present, had begun at the ages of 58, 54 and 13 years. The asymptomatic cases were 5, 33 and 36 years old.

Conclusions

One-third to one-half of the cases in each group are asymptomatic. The other cases have variable symptoms and signs which may suggest multiple sclerosis, syringomyelia and syringobulbia, or even brain tumour.

I would urge that all cases of syringomyelia and syringobulbia as well as those suspected of having multiple sclerosis be referred to the radiologist for examination of the region of foramen magnum. Certain cases have improved after surgical treatment of the above-mentioned conditions while others have had no progression of symptoms or signs after operation.

SUMMARY

28 cases of occipitalization of the atlas, 21 cases of pure platybasia and basilar invagination, 11 cases of separate odontoid process of the axis and 6 cases of chronic atlanto-axial dislocation are analyzed. One-third to one-half of the cases in each group were asymptomatic. The other cases had variable symptoms and signs which suggested multiple sclerosis, syringomyelia, syringobulbia or brain tumour.

ZUSAMMENFASSUNG

28 Fälle mit einer Okzipitalisation des Atlas, 21 Fälle mit echter Platybasie und basilarer Invagination, 11 Fälle mit isoliertem Zahnfortsatz des Epistropheus und 6 Fälle mit kronischer Dislokation zwischen Atlas und Epistropheus werden analysiert. Jeder zweite bis dritte Fall in jeder Gruppe verlief symptomlos. Die übrigen Fälle hatten variierende Symptome, welche an multiple Sklerose, Syringomyelie, Syringobulbie oder einen Hirntumor erinnnerten.

RÉSUMÉ

L'auteur présente 28 cas d'occipitalisation de l'atlas, 21 cas de platybasie pure et d'invagination basilaire, 11 cas d'apophyse odontoïde séparée et 6 cas de luxation atlo-axoïdienne chronique.

Dans chaque groupe, du tiers à la moitié des cas étaient asymptomatiques. Les autres cas présentaient des symptômes et signes divers qui faisaient penser à la sclérose multiple, à la syringomyélie, à la syringobulbie ou à une tumeur cérébrale.

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DISCUSSION

of Bony Abnormalities in the Region of the Foramen Magnum

H. M. Stauffer:

The material from our Hospital includes the original three cases reported by Chamberlain in 1937 which were treated surgically. In contrast to Dr. McRae's series, a number of our cases showed the combination of occipito-atlantal assimilation and basilar invagination. We have continued to use the relationship of the dens to the base line drawn from the posterior margin of the hard palate to the posterior margin of the foramen magnum as a satisfactory practical index of the degree of basilar invagination. Platybasia may be present but does not seem to be a very significant feature. Thickening of the dura at the cranio-vertebral junction was regularly encountered in the cases decompressed surgically and may be more important in constricting the cord and medulla oblongata than the bony abnormality.

The following is a summary of 11 cases of basilar impression treated surgically. The dens was 10—15 mm above the base line in 7 cases and 16—23 mm above in 4 cases. In 4 the basal angle was 145° or more. All cases showed, at surgery, constricting thickened dura. Nine cases showed post-operative improvement; the improvement was dramatic in 5 cases (age 16 to 50) with associated tonsillar herniation, and in 2 cases (11 and 20 years, respectively) without tonsillar herniation. Progress of the disease was arrested in one case and there was one post-operative death.

In a case of severe basilar impression secondary to Paget's disease air myelography demonstrated tonsillar herniation, very marked on one side. The post-operative result was excellent.

Four cases had no basilar impression and no occipito-atlantal assimilation but bony or dural constriction at the cranio-vertebral junction producing a similar clinical picture of cord compression. The air myelogram showed a partial block at the foramen magnum and there was very severe cord atrophy. A pantopaque myelogram was also done and from it the degree of cord atrophy would not be appreciated. We have found air myelography to be of particular value in studying lesions at the cranio-vertebral junction and in demonstrating atrophy of the cervical spinal cord.

FROM THE ROENTGEN DEPARTMENT (DIRECTOR: PROFESSOR ERIK LINDGREN),
SERAFIMERLASARETTET, STOCKHOLM SWEDEN

EXPERIENCES IN LOCALISATION OF BRAIN TUMOURS BY MEANS OF DIIODO^{131} FLUORESCEIN

by

S. E. Sjögren

For more than four years, diiodo^{131} fluorescein has been used to localise brain tumours. Very good results have been published, *e. g.* by MOORE, ASHKENAZY and other U. S. authors. For that reason we considered it interesting to test this method ourselves, particularly since an English paper from the Royal Cancer Hospital did not confirm the excellent American results. The following is only a brief report of our experiences.

Up to now, we have used a rather simple apparatus (Fig. 1). Two lead-shielded mica window Geiger tubes are supported on the movable arm of a dismantled roentgen tube support. Each Geiger tube is connected to a scaler. The two scalers start and stop synchronously, the results being easily calculated in counts per minute for each tube. Two channels were used mainly in order to shorten the time of the examination. A β-particle absorption plate and, in order to increase the collimation, a diaphragm were placed in front of the mica window (Fig. 3). Investigation of the accuracy as well as the reliability of the two channels was carried out. The apparatus seems to be comparable to that used, *e. g.* by ASHKENAZY et al. For example, it was easy to localise a concentrated activity of 7 ml with 0.15 μC/ml inserted into a volume of 1.4 litres of water, with a specific radioactivity 10 times lower and with the vessel wrapped in black paper. (The physical part of the investigation was made in co-operation with Mr. G. FREDZELL.) The diiodo^{131} fluorescein was obtained from Amersham. A dose of 1.5 mc was given. No problems of protection occurred during the administration as a temporary intravenous drip, percutaneously applied, was used. The injection time is, even so, easily kept short. No injuries occurred.

The measuring of the counting rate was started 30—45 minutes after the end of the injection. The Geiger tubes were placed at symmetrical

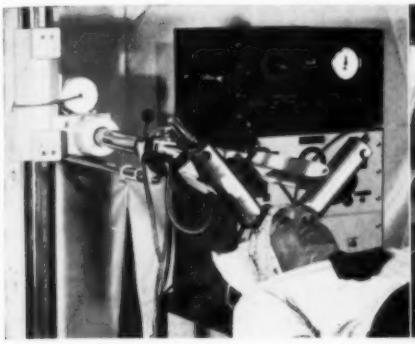

Fig. 1. Two-channel apparatus. The lead-shielded Geiger tubes, attached to the stand are adjustable. In the background: the two scalers.

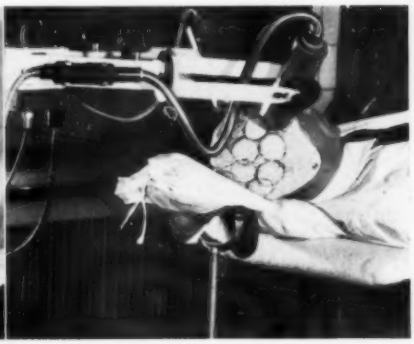

Fig. 2. Tubes in position for symmetrical bilateral measuring. On the table: bathing cap with markings and adjustable head rest.

positions on both sides of the midline of the skull. In order to facilitate the correct positioning of the tubes, a rubber bathing cap was used, on which 15 numbered circles had been traced on each side of the head, each circle corresponding to a standard area of examination. Great care was taken in applying the bathing cap correctly, and its position was sometimes checked roentgenologically. The so-called contact method for measuring was used, which means that the counter was placed against the head, at right angles to the tangent level of the point of contact. We have found that the correct placing of the Geiger tubes not infrequently is complicated and time consuming in spite of easily adjustable equipment. Incorrect adjustment seems to be a serious source of errors. Thus, under certain conditions, a 5 degree error of adjustment might cause an error in counting of 10—20 per cent. All standard areas were generally measured in every case simultaneously on the right and left sides. Areas with suspiciously high activity were checked repeatedly. The examinations were performed with the patient lying down (Fig. 2). After finishing the counting, an additional lateral roentgenogram, with the cap still in position, was taken with indicators on the areas showing the highest activity; the position of the fields was thus demonstrated.

Fig. 3. Diaphragm of this type, used in front of mica window, markedly improved the collimation.

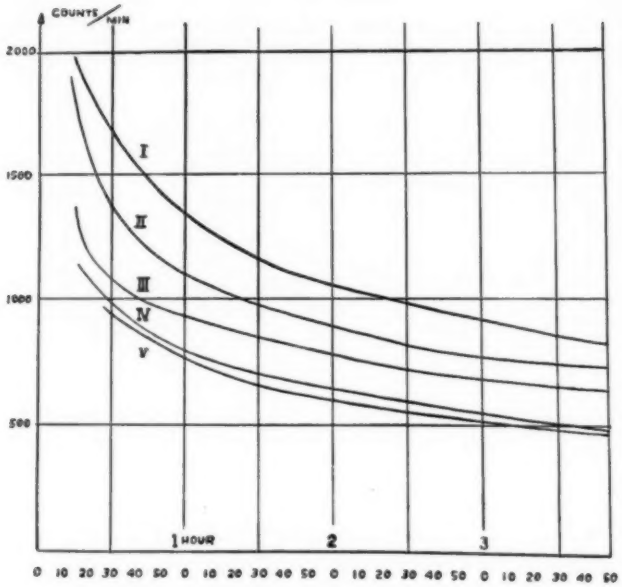

Diagram 1. The curves represent counting rate as a function of time in five different cases. (See text.)
Nr. I, II, V represent cases of meningiomata at the convexity.
Nr. III: a case of parasagittal malignant glioma.
Nr. IV: normal case.
Time 0 = end of injection.

Our material, consisting of 30 cases, all adults, is rather limited. In five of them, the counting rate as a function of time was studied and measured within one individual area determined in previous roentgen examinations as being situated directly above a tumour. The counting was started as soon as possible, and continued for several hours, in the beginning as frequently as every fifth minute. The results are shown by the curves in the diagram which are all of about the same shape. No significant difference in the time factor could thus be demonstrated between the three cases of meningiomas, the case of malignant glioma and the normal case. Since the measuring points are not identical in the various cases, the differences in the absolute counting rates cannot be evaluated.

In the remaining cases, the problem was that of localising intracranial lesions. The majority of these was brain tumours, but some other types of intracranial diseases as well as some normal cases also were represented, the examiner having no advanced knowledge of the nature of the condition. A difference in the counting rate between the two sides of the

head of 10 or even 15 per cent has not proved to bear any definite pathologic significance. In cases of marked asymmetry of the skull, the difference may be still greater. It was possible to localise, at least roughly, those tumours that were highly vascularised, especially the meningiomas. On the other hand, it was as a rule, not possible to localise poorly vascularised processes, and on one occasion it happened that the examination indicated a tumour in a position symmetrically opposite that of the actual tumour.

The question of the diagnostic value of the number of counts per minute recorded from the different areas of the skull will not be discussed in this context. In our cases no additional information has been obtained from the radio-dye test. Whether or not methods using radioactive isotopes would be of value in determining the nature of intracranial lesions was the main purpose of our investigation, but the result was negative. The localisation of lesions with this technique has also been unsatisfactory for clinical use.

Improved methods and/or new types of medium may, of course, in the future change the picture. The localising value must, however, always remain limited, the method being only a geometrical one and incapable of giving any information about the topography of intracranial pathologic processes. The importance of such information for a clear conception of, for example, the possibility of removing the lesion, is obvious, especially in view of the considerable displacement of brain tissue usually present in expanding processes. For these reasons, pneumography and/or angiography are therefore in our opinion always to be preferred.

SUMMARY

Radioactive diiodofluorescein has been tried in the diagnosis of intracranial lesions. A brief description of the technique and results is given. It was possible to localise, more or less roughly, the highly vascularized tumours in the limited material, but other kinds of lesions only occasionally. No additional information about the nature of the processes was obtained. In discussing the results, the author points out the limited value of radio dye methods in localising lesions: in contradistinction to the ordinary neuroradiologic contrast methods they are incapable of giving information about the topography of intracranial expanding lesions.

ZUSAMMENFASSUNG

Radioaktives Dijodfluorescin ist in der Diagnostik intrakranieller Veränderungen versuchsweise angewendet worden. Es wird eine kurze Beschreibung der Technik und der Ergebnisse gegeben. Es war möglich, die stark vaskularisierten Tumoren in dem begrenzten Material mehr oder weniger genau zu lokalisieren. Keine zusätzliche Information über die Art der Prozesses wurde erhalten. In der Diskussion der Ergebnisse hebt der Verf. den begrenzten Wert der Methoden mit radioaktiven Farbstoffen zur

Lokalisation von Veränderungen hervor; im Gegensatz zu den üblichen neuroradiologischen Kontrastmethoden sind sie nicht in der Lage, Informationen über die Topographie intrakranieller expansiver Veränderungen zu liefern.

RÉSUMÉ

L'auteur a expérimenté la diiodofluorescéine radioactive dans le diagnostic des lésions intracraniennes. Il décrit brièvement la technique et les résultats. Il a pu, sur un nombre limité de cas, localiser, plus ou moins grossièrement, les tumeurs très vascularisées, mais, seulement dans quelques cas, les autres types de lésions. L'examen n'a pas fourni de renseignements supplémentaires sur la nature des lésions. Dans la discussion des résultats, l'auteur souligne que, pour la localisation des lésions, la valeur des méthodes de colorations radioactives est limitée; au contraire des méthodes neuroradiologiques de contraste habituelles, elles sont incapables de renseigner sur la topographie des lésions expansives intracraniennes.

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FROM THE ROENTGEN DEPARTMENT (DIRECTOR: PROFESSOR ERIK LINDGREN), SERAFIMERLASARETTET, STOCKHOLM, AND THE RESEARCH LABORATORY OF GEORG SCHÖNANDER AB., STOCKHOLM, SWEDEN

APPARATUS FOR SERIAL ANGIOGRAPHY

by *S. E. Sjögren* and *Georg Fredzell*

I. RADIOLOGIC VIEWPOINTS

by

S. E. Sjögren

An automatic film changer is suitable for cerebral angiography only if it adds no difficulties to the examination. It must, therefore, fulfil certain requirements, among which the following are some of the more important:

1. The size of the serial film must not be smaller than the ordinary film employed.

2. It must be possible to carry out the percutaneous puncture unimpeded with the patient in position. There must be room for an assistant and sufficient protection from irradiation.

3. Due regard must be paid to the necessity for various selectable projections, both in the a. p. and oblique planes, to be obtainable in order that the examination may be a complete one.

4. With the correct technique, lateral views are taken with a horizontal projection of the central beam, and no exception to this rule should be made in serial angiography. For this reason the film area of the changer must be situated close to the edge of the apparatus and close to the patient's shoulder, so that short-necked individuals may be examined without difficulty.

5. It must be possible to obtain test films which can be developed immediately; before commencing the serial examination it is of course necessary to know if the needle has been introduced into the artery required.

6. There must also be provision for the immediate development of

the serials. It is only by viewing the wet films that it is possible for the examiner to decide the next step in the procedure.

7. Simultaneous exposure in two planes, as used for example in angio-cardiography, is not convenient for cerebral angiography in which fine definition is of considerable importance. If two simultaneous series are required the respective films must be obtained with alternating exposures.

8. Finally, it is an advantage if the changer does not make more noise than necessary. The patient's ear lies close to the apparatus.

Certain of these requirements demand that the film changer be small in size. The ordinary types, made for other purposes, cannot be used directly for cerebral angiography. A special apparatus, the technical details of the construction of which are described by Mr. FREDZELL, has been constructed by Georg Schönander AB. in collaboration with the Roentgen Department of Serafimer Lasarettet and with due consideration to the above desiderata. It is, as regards the actual film size, built directly for cerebral angiography. A most valuable contribution to the examination is the E. C. G. recording of the exposures and the injection time taken during the series. This, at least, is necessary before any study of the circulation rate can be made.

We have worked since July 1952 with this film changer, and have obtained preliminary results. As yet, it has been fixed on a temporary stand and used only for lateral views, the investigation being completed with the help of an ordinary manual cassette holder for the a. p. and oblique projections. The question of using the changer in the future for routine work has not been definitely decided. It must be possible to adapt it in some way if it should be employed during an angiography started in the ordinary manner. The changer has been used in twenty-eight series of cerebral angiography. All these have been taken with three films per second and almost a maximum number of films (twenty-five) have been used on each occasion. The skin dose will not exceed 30 r in such a series of twenty-five films with the exposure technique used: 24—27 mAs at 85 to 90 kVP and a focus-film distance of 80 cms.

Rapid serial angiography is best performed with slightly less contrast medium than is normally used. We have actually found a dose of 5—6 mls to be suitable. Too much contrast medium often fills out the arteries and veins simultaneously on a number of films, and adversely affects the interpretation. In the venous phase, a speed of three pictures per second appears, in almost all cases, to be much too high. We have, however, not yet made use of the possibility offered by the apparatus of taking the arterial phase films faster than the venous.

Fourteen of the series have shown expanding processes and in nine of these, highly vascularized tumours were present. In certain of these cases it is improbable that we should have obtained the same result with a manual cassette changer.

There is no doubt that in certain instances a rapid film changer together with the large amount of available film, increases the value of cerebral angiography, and is sometimes necessary when special information is required. Various conditions in which this obtains have been discussed more than once in the recent literature, and for this reason will not be outlined.

II. TECHNICAL CONSTRUCTION

by

Georg Fredzell

The need for improved technical aids for the further simplification of routine work as well as for continued progress in the neuro-radiologic field has been pointed out on several occasions. Many types of examinations, such as cerebral angiography, could hardly be performed without a device permitting of the taking of a rapid series of roentgenograms. By means of a manually operated cassette-changer fixed on the Lysholm skull table, initial and very important aid was given in this respect. However, this device has sometimes proved to be inadequate, owing to the obvious necessity of decreasing the intervals between the exposures and thus of increasing the number of films obtained.

For some ten years past Georg Schönander AB has been thoroughly studying this problem and has designed a number of various kinds of serial changers, mostly for angiocardiography. The possibility of employing such existing serial apparatus for cerebral investigations was therefore duly considered. However, it appeared that there were no types of changers in production that could be successfully adapted for cerebral examinations, all being too large and inflexible. Consequently, a new changer had to be made. We here wish to acknowledge the assistance afforded us by the Director of the Roentgen Department of Serafimer Lasarettet in placing the experience of his staff at our disposal and thus enabling us to arrive at a suitable and practical basis for the design.

In spite of the fact that we have at our disposal a mirror camera with a very high degree of luminosity, there was no doubt concerning the advantages of direct roentgenography, employing full-sized films, over indirect photofluorography. We had also, some years previously,

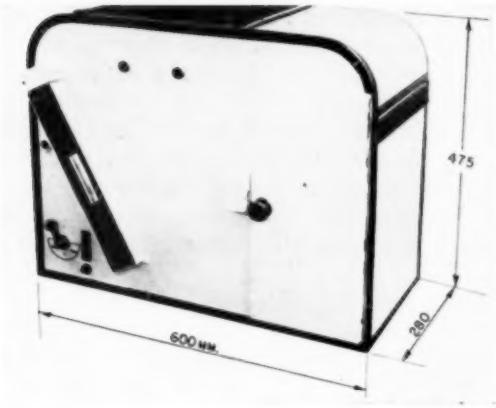

Fig. 1. Exterior of apparatus.

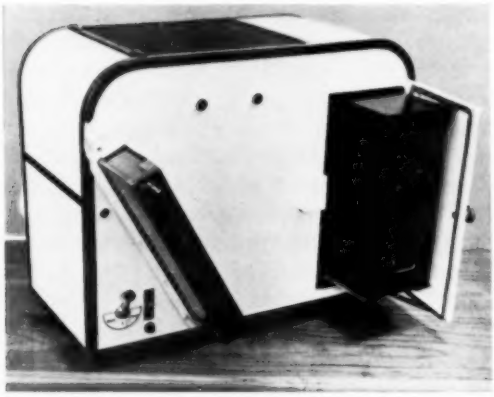

Fig. 2. Magazine partially withdrawn. Magazine for unexposed film to the right.

made up our minds regarding another principle, *i. e.* the question of whether to use separate film sheets or roll-film.

We consider the roll-film technique a makeshift that should, if possible, be avoided. It entails, for instance, the serious drawback of deranging the darkroom routine and necessitates storing film rolls, which otherwise are not always available. Moreover, special devices for the development and fixing of the film have to be installed.

Fig. 1 shows the apparatus called 'the AOT-changer'. The size of the film used is 12″ × 10″ or 24 × 30 cm, but the apparatus will also be constructed for larger films such as 14″ × 14″. The maximum number of films per series is thirty, the maximum exposure rate being six films per second. The main feature is the employment of separate film sheets without cassettes or any kind of support. In this way the mass to be accelerated is reduced to its theoretical limit; the film sheet itself. This is most desirable in a reliable film changer of small dimensions and relatively high speed.

Fig. 2 shows the main parts of the AOT-changer, viz. the two magazines and the light- and ray-proof container, in which the films are transferred from the magazine for unexposed films into the other magazine via the exposure field, where, pressed between two intensifying screens, they are exposed.

The two magazines are light-proof and may thus be carried between

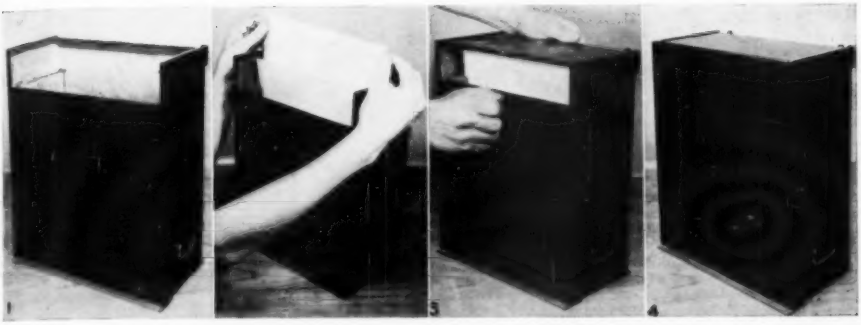

Fig. 3. Various phases in loading of magazine.

the dark room and the examination room without any special precautions.

Fig. 3. The magazine to be loaded is in the form of a rectangular case, the height and width of which depends on the size of the film, and the depth on the maximum number of films to be used. The type shown takes 30 films. There must be a certain separation between the individual sheets, and for this reason they are inserted into grooves at the bottom and sides of the magazine. The distance between the centres of the grooves is 4 mm.

At the lower part of the front side of the box are two rectangular holes through which the device that draws the films out of the magazine engages with their lower edges. The magazine becomes light-proof as soon as the lid and the upper part of the front side are slid to a position in which they meet and become interlocked. Two rails for positioning the case in the changer lie at the bottom of the magazine and for the same purpose the lid has two hooks at its rear end. The carriage on which the loaded magazine is placed is moved along a screw-threaded shaft, which is synchronously driven by a chain transmission at the same speed as the shaft between the feeding wheels.

Fig. 4. A cam on the threaded shaft activates a spring-supported balance system with two beams for a short period in each revolution and to which it imparts an up-and-down movement.

On the shaft between the wheels are two more cams. During another short period in the cycle one of these cams raises a rubber-covered metal rod. This serves as a safety device and holds the film in the correct position, while the other causes the plate that carries the lower intensifying screen to move up and down. In this way free passage during transfer and sufficiently good compression during exposure are assured.

The exposed films enter the collecting magazine through a narrow

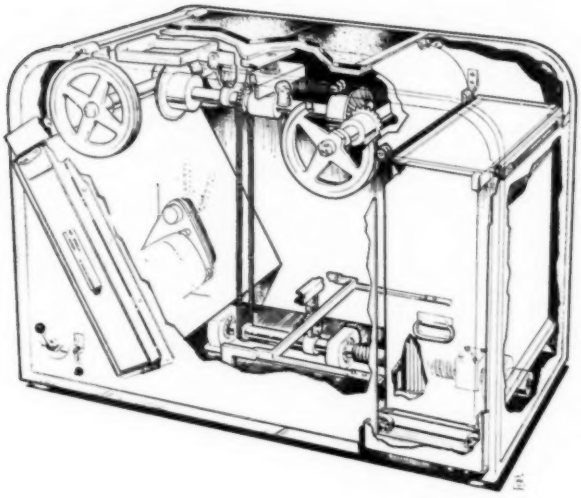

Fig. 4. Diagram of interior of magazine.

slit at the upper right-hand corner. By means of a small lever the slit may be shut so that the container becomes light-proof. When the magazine is closed it may be taken out of the apparatus and carried to the darkroom, where the films at the bottom of the magazine are removed.

A number of metal sheets and guides, which control the movement of the films are incorporated in the apparatus.

Fig. 5 a and b illustrate two different phases of the process in the changer.

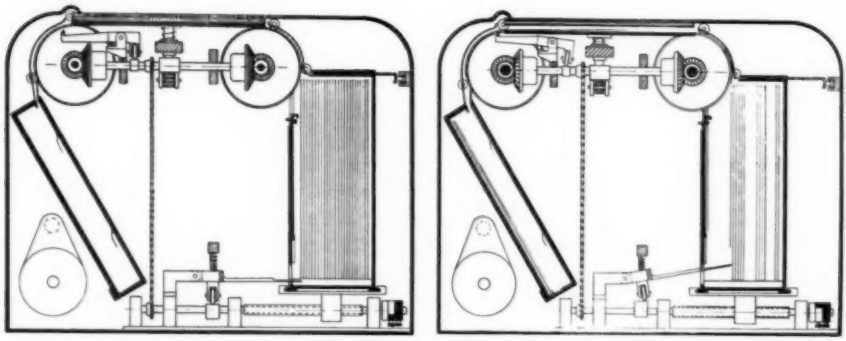

Fig. 5. Different phases of the process in the changer.
(a) Position just before the beams remove the first film from magazine.
(b) The beams are just pushing one film out of magazine.

Fig. 5 a shows the position just before the beams of the balance are ready to remove the first film from the fully-loaded magazine. The beams have entered the magazine through the holes but are not yet raised. In Fig. 5 b on the other hand, the beams are just pushing one film out of the magazine, and simultaneously the preceding film is carried from the exposure field down to the collecting magazine. Should a constant rate not be required during the examination, a change to one-half or one-third of the maximum speed is readily made by omitting a certain number of grooves in the magazine. Any desired exposure programme may thus be chosen beforehand, with a consequent saving of film.

The exposure field of the apparatus is provided with a fine cross-hatch grid covered by a bakelite sheet. Exposures are automatically controlled by means of built-in micro-switches and contact segments, which ensure that energy is only applied when a film is ready for exposure between the intensifying screens. Unloading intervals in the film magazine will thus not expose the patient to undesirable doses of irradiation. Further, safety switches ensure that the apparatus is properly shut so as to be light-proof and correctly adjusted for working conditions before the examination is started. It may be mounted in any position excepting upside down, in which case the films drop from the loading magazine.

An important question in connection with the use of all serial devices is that of choosing the most suitable roentgen generator.

A single-plane changer necessitates the energization of only one tube. The main problem is then to secure the required degree of precision and to obtain intervals as short as are needed between the exposures.

Suitable exposure data for cerebral investigations with the changer described are 25 mAs at 85—90 kVP. This means that almost any medium-sized roentgen apparatus may be used if fitted with a 50 kW tube, provided that the timer of the unit enables the exposures to be made at a maximum rate of six per second. This last requirement is very seldom fulfilled, however. For this reason a special electro-mechanical single-phase contactor has been constructed. The contactor synchronizes itself to the main supply frequency and is connected to a timer giving selectable exposure times between 0.02 and 0.10 seconds.

The contactor device is small and inexpensive and may be connected directly to the changer so that the complete unit may be linked to most 4-valve generators.

The contactor however, cannot be connected to three-phase generators, for which it is necessary to use an electronic contactor device; the latter is, however, considerably more costly and complicated.

Owing to the simple mechanical and electrical design, the AOT film

changer for cerebral examinations may be used as an auxiliary apparatus for advanced roentgen work with roentgen equipment already installed. In general, a tube normally intended for use with a Bucky couch or a motor-driven tilting couch may also be used as a source of radiation for angiographic examinations.

SUMMARY

The radiologic considerations governing the employment of serial devices in cerebral angiography are firstly discussed. It is pointed out that the value of certain examinations may be enhanced by an increase in the number of films taken. A description follows of a recently designed apparatus for rapid serial angiography and by which up to thirty roentgenograms at a maximum exposure rate of six films per second may be obtained.

ZUSAMMENFASSUNG

Die radiologischen Erwägungen, die für die Anwendung von Serienaufnahmevorrichtungen bei der zerebralen Angiographie bestimmend sind, werden zuerst besprochen. Es wird darauf hingewiesen, dass der Wert gewisser Untersuchungen durch Erhöhung der Anzahl der hergestellten Röntgenaufnahmen gesteigert werden kann. Es folgt die Beschreibung einer kürzlich fertiggestellten Apparatur für schnelle Angiographieserien; man kann damit bis zu 30 Röntgenaufnahmen mit einer maximale Exponierungsgeschwindigkeit von 6 Filmen pro Sekunde erhalten.

RÉSUMÉ

Les auteurs étudient d'abord les considérations radiologiques qui règlent l'emploi de dispositifs de prise de clichés en série pour l'angiographie cérébrale. Ils soulignent que l'augmentation du nombre des clichés peut accroître l'intérêt de certains examens. Ils décrivent un appareil d'angiographie en série rapide récemment créé, qui permet d'obtenir jusqu'à trente clichés, à la cadence maximum de six clichés par seconde.

SURVEY OF THE SYMPOSIUM

by

H. Fischgold

I feel that so many innovations have been brought into this Symposium that I may be permitted to conclude with one final innovation. In place of the usual conclusions and expressions of regret which are always associated with the end of a Meeting like this, one should try to formulate in a short summary the work which has been achieved. A Symposium is arranged in order to pose certain problems clearly and to find at least provisional solutions.

The first question was that of tumours of the vertebral canal; we found that the 'discovery of Sicard' had been completed and, indeed, been carried further; we now see that it is not sufficient to observe that blocking of the spinal canal has occurred, but may also make inferences as to the histology of the process; we may also presume whether the tumour is intra- or extra-dural. This further step represents the enormous progress now being realised.

It is quite evident that seriographic technique is being established, and in the future we have to make the choice between three techniques: seriography on continuous or roll film; seriography on cut film without casettes; and seriography on film in casettes. These three methods represent different solutions and it is extremely important for us to know that they exist. The months and years to come will show us which of them we are to adopt in cerebral angiography.

One of the most important conclusions to be drawn from the work of the Symposium is that care must be observed in examining a frontal angiographic view to see whether there is any projection of the veins to the other side of the median line. This is a new sign quite as important as the displacement of the anterior cerebral artery towards the healthy hemisphere.

Concerning vertebral angiography, the importance of this subject is clear from this Symposium. At Rotterdam we had not gone so far: three years ago we learned about a method of technique which made it possible to demonstrate the vessels of the posterior fossa and saw the first

results. At this Meeting we have seen the further results and may say that at least a pathognomic sign has been established for the multiple tumours of Lindau; this is something quite new. Vertebral angiography compels us to continue our perpetual study of anatomy, otherwise there would be no possibility of a valid radiologic Symposium.

We have seen that a diagnosis may be made from the displacement of vessels in the posterior fossa and we now know that certain tumours may be recognized by means of vertebral angiography. The period during which we were feeling our way in vertebral angiography, is at an end. At last we have set foot on land and it only remains for us to conquer the immense regions and grasp the opportunities before us.

Encephalography, a method established during the last ten years by ROBERTSON and LINDGREN, is still considered with considerable reserve by certain authorities on the Continent and should be verified and tested. This is important and we should all do our utmost, when we return to our own countries, to apply the procedure.

Tomography, I shall not say very much about because I am particularly interested in the subject and very pleased to see so much attention being paid to it. As our Chairman has said, we shall see what had been done in this field in various countries at the next Symposium.

When I was at the Drottningholm Theatre the other day, a thought occurred to me: a little more than two centuries ago, Gustav III, King of Sweden journeyed to Paris where he saw the little theatre of Versailles and from which he brought back the machinery, the scenery, the plays and the actors to his native land.

When, in turn, we return home, we shall take with us the science and the technique of Swedish neuro-radiology. This will be the measure of our free and peaceful revenge.

Mr President, Professor LINDGREN and Mr Secretary, Dr. LINDBOM, we thank you!